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THE EFFECT OF REPEATED FIRING UPON THE SPECIFIC GRAVITY AND MICROSTRUCTURE OF SOME ALUMINUM-SILICATE MINERALS*

By Frank Harwood Riddle† and Albert B. Peck‡

Abstract

Repeated firing of several aluminum-silicate minerals to the same temperatures show that the specific gravities of the fired products do not drop at the same rate. Petrographic-microscopic examinations show that this is due to different rates of dissociation in the minerals. While these rates of reaction or dissociation can not be measured accurately, some idea of the relative rates can be obtained by comparison of the sizes of completely dissociated grains of the minerals or of the widths of the borders of the dissociation products formed around the grains. Furthermore, the effect of repeated firing upon the increase in size of mullite crystals formed when the minerals dissociate gives evidence concerning the rate of growth or probable refractoriness of the minerals. These are described in some detail and close correlation between them and the specific gravity changes are pointed out.

I. Introduction

Some years ago, Peck[1] published data on the changes in specific gravity occurring in andalusite, kyanite, and sillimanite, the trimorphous forms of the compound, $Al_2O_3 \cdot SiO_2$, when fired to cone 15. Two of these, andalusite and kyanite, showed definite alterations in microstructure as well as in specific gravity. The change in specific gravity of andalusite was small, while that of kyanite was large. Sillimanite showed no changes in microstructure but did show a slight decrease in specific gravity. The figures follow.

	Specific Gravity	
	Original material	Fired to cone 15
Andalusite	3.29	3.20
Kyanite	3.59	3.09
Sillimanite	3.15	2.92

The fact that these minerals, after firing, did not show the same specific gravity could be accounted for, at least in part in the cases of andalusite and kyanite, by the presence of impurities or by the incomplete decomposition of some of the larger grains into mullite and glass. The explanation in the case of sillimanite was not so simple, since it was not fired as high as its decomposition point and, furthermore, was reasonably pure except for a small amount of muscovite. It seemed probable that the difference was due mainly to the formation of microscopic cracks by the thermal expansion of the mineral. In the particular work mentioned, interest was not centered primarily in the specific gravity changes in the pure minerals but rather in the points at which the microstructure changed under commercial firing conditions, using material of such purity as might be expected for use in actual production of ware.

II. Purpose

The wide range noted in the specific gravity of the end products led to further investigation of what would happen when pure or nearly pure minerals were used. A number of questions present themselves: (1) whether these minerals, when decomposed, give a product in all cases having the same specific gravity as would be expected from a consideration of their original chemical composition before firing and of their mineral constitution after firing, and (2) if they do attain the same specific gravity, does this take place at different rates when subjected to the same temperatures. Since experimental work was also being done upon dumortierite at this time, it was included in the investigation, although of somewhat different chemical composition from the others.

III. Selection of Material

Still clinging to a certain extent to commercial material rather than making use of minerals of gem quality, the minerals in each case were crushed to coarse granules and carefully sepa-

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† Director of Research, Champion Spark Plug Co., Ceramic Division, Detroit, Mich.

‡ Associate Professor of Mineralogy, Univ. of Michigan, Ann Arbor, Mich.

[1] A. B. Peck, "Changes in the Constitution and Microstructure of Andalusite, Cyanite, and Sillimanite at High Temperatures and Their Significance in Industrial Practice," *Jour. Amer. Ceram. Soc.*, **8** [7] 407–29 (1925).

rated by hand from other minerals present. Since the writers were especially interested in the possible behavior of andalusite, two samples of this were secured. One was a crystal,[2] almost perfectly pure after the outer coating of adhering alteration products had been removed. The second sample was selected from rose red crystals.[3] One sample of kyanite was used, which consisted of a large crystal,[4] very free from other minerals except a trace of muscovite. The sillimanite was

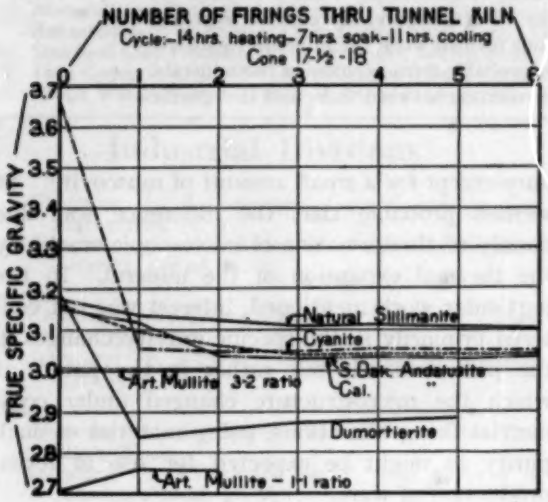

FIG. 1.

a pure fibrous variety.[5] The dumortierite[6] was rather fibrous and schistose.[6] None of the samples, except the dumortierite, contained more than 5% of impurities in the form of other minerals, mainly muscovite. About 10% of this was present with the dumortierite. The selected minerals were crushed in a steel mortar to 100-mesh, and the iron was removed with a magnet.

IV. Firing

About 50 grams of each mineral were placed in an unglazed "sillimanite" crucible. These were fired with the regular ware[7] on a schedule calling for cone 17½ to cone 18 to be reached in 14 hours with a 7-hour "soak." The actual temperature attained was 2635°F. In all, the samples were fired six times in this manner.

[2] From the mine of Champion Sillimanite, Inc., in California.
[3] From Custer County, S. D.
[4] From Cardigan, N. H.
[5] From Oreana, Palmer County, Nev.
[6] A. B. Peck, "Dumortierite as a Commerical Mineral," *Amer. Mineral.*, **11** [4] 96–101 (1926); *Ceram. Abs.*, **5** [12] 420 (1926).
[7] Harrop tunnel kiln, Champion Porcelain Co.

V. Specific Gravity Determinations

After each passage through the kiln, a sample about 7 grams in weight was taken from each crucible. The specific gravity determination was made upon this sample using the standard pycnometer method with careful boiling. The results are shown in the following table and curves (Fig. 1).

TABLE I
SPECIFIC GRAVITY

No. of times fired	Andalusite		Kyanite	Silli-manite	Dumor-tierite	I	II
	Calif.	S. D.					
0	3.154	3.158	3.665	3.176	3.182	3.048	2.70
1	3.104	3.096	3.056	3.132	2.835	3.061	2.76
2	3.036	3.056	3.046	3.124	2.851	3.062	2.75
3	3.032	3.035	3.044	3.108	2.868		
4	3.033	3.035	3.053	3.112	2.877		
5	3.030	3.038	3.047	3.107	2.885		
6	3.034	3.036	3.047	3.102			

I Artificial mullite (Norton Co.) $3Al_2O_3 \cdot 2SiO_2$.
II Artificial mullite (Norton Co.) $Al_2O_3 \cdot SiO_2$.
* Specific gravity of pure artificial mullite, 3.156.

* J. W. Greig, "Formation of Mullite from Cyanite, Andalusite, and Sillimanite," *Jour. Amer. Ceram. Soc.*, **8** [8] 465–84 (1925).

VI. Discussion of Curves

It requires only a glance to see that the specific gravities of andalusite, kyanite, and sillimanite, after the fifth firing, all approach closely to the value of 3.031 given in earlier work by Shepherd, Rankin, and Wright[8] for "sillimanite," which subsequently has been shown by Bowen and Greig[9] to be a mixture of mullite and a siliceous glass. As will be shown by the later microscopic examination, all of the minerals used, with the exception of sillimanite, show this same mixture when decomposed by firing to cone 18. The greatest decreases in specific gravity are shown by kyanite and dumortierite, that of kyanite being by far the most pronounced. By comparison, that of the two samples of andalusite is small, and the decrease in the case of sillimanite is very small. The decreases in the two andalusites persist through two firings and then remain almost stationary during the remainder. The later microscopic observations will show the cause of this.

In contrast to the gradual drop after the first firing, which takes place in andalusite, kyanite,

[8] E. S. Shepherd, G. A. Rankin, and F. E. Wright, "The Binary Systems of Alumina with Silica, Lime, and Magnesia," *Amer. Jour. Sci.*, **28** [10] 293–333 (1909).
[9] N. L. Bowen and J. W. Greig, "The System Al_2O_3–SiO_2," *Jour. Amer. Ceram. Soc.*, **7** [4] 238–54 (1924); **7** [5] 410 (1924).

and sillimanite, dumortierite slowly increases in specific gravity with repeated firing. The writers can not account for this and for its pronounced initial decrease unless it be due to impurities present in this material, which are not present in the others. It is true that there was about 10% of muscovite present in the material used for the dumortierite determinations, and this may have some bearing upon the results. If the dumortierite were pure, the product of its dissociation would be expected to have a higher specific gravity than that formed from one of the members of the sillimanite group, because its alumina content is higher than that of those minerals.

It is possible also that the products formed by the dissociation of muscovite in the early firing may combine under the influence of later repeated firings to form a mixture of mullite, cristobalite, and leucite. Such reaction would be accompanied by a slight increase in specific gravity.

While sillimanite shows the least change in specific gravity, it is not necessarily the most refractory of these minerals at temperatures much higher than cone 18 because when it eventually decomposes the resulting mixture of mullite and glass may not be as refractory as the decomposition product of dumortierite. Theoretically, dumortierite should be the most refractory of these minerals because its ratio of 4 Al_2O_3:3 SiO_2 is nearer that of mullite (3:2) than is the ratio of sillimanite (1:1). The temperature of decomposition of these minerals is not necessarily a measure of their true refractoriness at elevated temperatures. Thus, as will be shown later from microscopic studies, dumortierite has the advantage of breaking down at comparatively low temperatures and of being more or less stabilized, as it were; at the same time it also produces a theoretically more refractory mixture.

For purposes of comparison, the curves of two samples of electrically fused mullite have been included. Since they already represent a product stable at the higher temperatures, their curves show little change although the specific gravity of the product having the 1:1 ratio is rather low. This is probably due to sealed gas cavities which are present.

VII. Changes in Microstructure

Previous work[10] upon certain of these minerals has shown that they undergo distinct changes in microstructure at various temperatures under different conditions of heating and with material of different purity. Since the writers were interested in the petrographic-microscopic method of attack as a means of explaining some of the variations noted in the specific gravities, a microscopic examination was made of each of these materials after each specific gravity determination was completed. All observations were carried out independently and in many instances quite close agreement was obtained between the results, as will be pointed out shortly.

(1) Andalusite

Most of the detailed description of the changes in microstructure may be omitted, except as they have a direct bearing upon the specific gravity values. In the case of both California and South Dakota andalusite, it was found that decomposition of the smaller grains into mullite and glass had been completed with the first firing while that of the larger grains was only partial. This gives rise to the formation of fibrous borders which have been noted previously.[11] In the present specimens two observations are worthy of mention.

First, these crystalline borders varied in width even upon the same grain from 0.0003 to 0.0007 inch. It was noticeable that the widest part of the border was almost always in the same direction as the vibration direction of the "fast ray" of the andalusite still forming the undecomposed center. It may perhaps be inferred from this that andalusite transmits heat more rapidly in this direction. It is also possible that variations in thickness of the grains may have something to do with this development of the border, although it does not appear probable that such uniformity of development would result from this cause.

The second feature of the first firing was that the alteration borders of the California andalusite usually appeared to be slightly wider than those of the South Dakota mineral, less South Dakota material being decomposed. This may be due to greater purity of the South Dakota andalusite in the form of smaller amounts of natural fluxes. It is to be noted that the specific gravity of the South Dakota mineral slightly exceeds that from California.

The result of the second firing was to decompose

[10] N. L. Bowen and J. W. Greig, see footnote 9; A. B. Peck, see footnote 1; and J. W. Greig, see * footnote accompanying Table I.

[11] See footnotes 1 and * accompanying Table I.

the andalusite further, but the two samples showed marked differences. It was estimated that the California andalusite was 95% decomposed, while the other was about 65 to 75% altered. This also is in line with the specific gravity values which show approximately 100% and 80% decomposition, assuming that the final specific gravity of pure material would be 3.031, *i.e.*, the theoretical value. Where crystalline decomposition borders and unaltered centers were present in the same grain, the borders were usually more than twice as wide as in the same material fired but once. Apparently the reaction progresses at an increasing rate with time. The effect of the additional firing is also seen in the slightly larger mullite crystals formed.

The only results of further firings are the completion of the decomposition and a slow increase in the size of the mullite crystals, although they never exceed 0.001 inch in length and 0.0001 inch in width.

(2) Kyanite

Previous investigations have pointed out that kyanite breaks down easily at comparatively low temperatures and it was not surprising to find that, as a result of the first passage through the kiln, even the largest fragments had been entirely decomposed. The grains frequently showed a typical envelope-shaped development of the mixture of mullite crystals and glass, as described by Greig. Some of the crystals formed reached a size of 0.001 inch in length and 0.0002 inch in width. This is indicative that not only does kyanite decompose at a lower temperature than andalusite but that there is also some factor which enables the mullite crystals to grow more easily. Possibly this is due to the longer temperature interval during which the siliceous glass has been able to act as a medium for crystal growth.

Decomposition of kyanite does not appear to be uniform; that is, some grains give large crystals of mullite, some small crystals, and others both large and small. In view of the high purity of this kyanite, it is difficult to explain this variation except on the basis of optical orientation: that larger crystals are formed in some directions than in others, as pointed out by Greig.[12] In some ways this is analogous to the variable widths of the borders formed upon andalusite.

The complete breakdown of kyanite microscopically during the first firing would indicate a large and practically final change in specific gravity. This is actually true, since subsequent firings produce very little further decrease. The only microscopic change, which occurs in the five later firings, is a gradual enlargement of the mullite crystals. By the fifth firing these may have attained a size of 0.002 inch in length and 0.0002 inch in width.

(3) Sillimanite

According to the work of Bowen and Greig, no change taking place in sillimanite at cones 17 to 18 would be expected, since sillimanite shows no decomposition until 1545°C is reached. Incidentally, this is the highest temperature at which any aluminum silicate, in which the oxides are present in the proportion of 1:1, can exist without dissociation.

The first firing did not affect the optical properties of sillimanite itself, but it did cause decomposition in the small amounts of mica which accompanied the sillimanite. In fact, the latter is unaffected by any but the fifth firing. Here some of the sillimanite crystals show a few minute rounded glassy inclusions of indeterminable character. These may represent the beginning of the formation of globules of silica as described by Bowen and Greig, but they may also, in this material, be inclusions of fused mica. In the absence of more definite data one is inclined toward the latter possibility.

It can be definitely stated, however, that there are no marked changes in microstructure as in the other minerals. Furthermore, the time factor is apparently small at the temperatures employed.

In view of the lack of distinct microscopic changes in sillimanite, the gradual decreases in specific gravity must be due to alterations in the associated minerals, in this instance principally muscovite. The fact that the values are higher than those obtained by Peck[13] can be accounted for by the greater purity of the sillimanite used in the present study.

(4) Dumortierite

Viewed from its apparent refractoriness as based upon the position of its chemical composition in the silica-alumina diagram, one might not expect dumortierite to break down at such a low temperature as cone 6 or even less, in spite of pre-

[12] See * footnote accompanying Table I.

[13] See footnote 1.

vious experience which had shown that kyanite had a low decomposition point. By microscopic examination of draw-trial samples it has been established[14] that small dumortierite grains may be partially decomposed at cone 6 into a mixture of very small grains with glassy material between them. The average refractive index of the mixture is about 1.63. From its chemical composition one may infer that the minute grains are incipient mullite crystals and that possibly the glass is a borosilicate. Complete decomposition of larger dumortierite fragments is accomplished at cone 13. Meanwhile, there is a marked resistance of the mullite to an increase in the size of the crystals and this persists up to cone 18 and perhaps even beyond that point.

Since the present samples were fired directly to cone 18, complete dissociation into shapeless crystals in a glass resulted. The crystals do not exceed 0.00005 inch (1.25 micron) and are slightly higher in proportion to the glass than in the decomposition products formed from members of the sillimanite group. This would be expected from its chemical composition. The sharp outlines of the original dumortierite crystals are frequently preserved. So far as can be observed in these samples, there appears to be no relation between the orientation of the mullite crystals and that of the original grain.

The second firing shows slight enlargement of the mullite crystals, which begin to exhibit elongated forms. There are some indications also that the mullite has an opposite orientation to that of the original dumortierite, but this orientation is not as pronounced as in andalusite and kyanite.

The three subsequent firings are repetitions microscopically of the second. There is a slight growth of the crystals until they may attain a length of 0.0001 inch. Doubly refracting areas are also more numerous, again indicating growth in the size of the crystals.

As a result of the foregoing data, it is to be expected that a sudden decrease in specific gravity would take place during the first firing. The gradual rise in the curve thereafter is probably due to the progressive changes in both the dumortierite and the associated minerals, the latter of which is known to have been chiefly muscovite to the extent of 10% or more. It is undoubtedly the breakdown of this mineral which carried the specific gravity so low upon the first firing. The lower specific gravity may also be due to the presence of a borosilicate glass of lower density than the silica glass formed from the sillimanite minerals.

As suggested earlier, perhaps combination of the initial decomposition products results in the later increase in specific gravity.

The general impression gained from the changes in microstructure of dumortierite is that it is apparently very refractory, crystal growth being quite resistant to prolonged heating at temperatures considerably in excess of its decomposition point, even though the latter is low. The time factor is probably small.

VIII. Some Relations to Practical Use

The progressive dissociation of large fragments of andalusite may be utilized to advantage in refractories as shown by Riddle.[15] During the initial firing of an andalusite-corundum brick, the larger grog fragments of andalusite are only partially dissociated and the action is gradually completed with use at high temperatures. The slight expansion, which occurs during use, results in a desirable closer packing of the refractory into the wall, which is permanent.

A second result is caused by the reaction between the corundum and the excess siliceous liquid set free during dissociation. This causes an increasing amount of mullite crystals to be formed in the bond of the refractory over a considerable period of time, with consequent increase in refractoriness and in resistance of the body against deformation.

In these ways, andalusite appears to have a distinct advantage. Kyanite, because of its excessive expansion, requires pre-calcination. Dumortierite does not require previous calcination but, like kyanite, even large grains dissociate rapidly and completely and the advantage of gradual dissociation is lost. Sillimanite is inert except at temperatures far above normal practice.

IX. Summary

Specific gravity and optical data confirm each other as to the final decomposition products and the order and rate of decomposition of the minerals of the sillimanite group upon repeated firing to cones 17 to 18. In order of decreasing ease

[14] Unpublished data.

[15] F. H. Riddle, "The Possibility of Sillimanite Minerals as Refractories," *Trans. Electrochem. Soc.*, 59, 35–51 (1931).

of decomposition, they are kyanite, andalusite, and sillimanite. A fourth mineral, dumortierite, shows a decomposition point lower than kyanite. The resulting products are much the same as those of the sillimanite group.

The sharp decrease in specific gravity of kyanite and dumortierite is due to their easy and complete breakdown. Andalusite shows a slow decrease through two firings, due to progressive dissociation of the larger grains. The gradual decrease in the specific gravity of sillimanite is not due to changes in sillimanite itself but to those of the associated mineral impurities.

The time factor, as expressed by the enlargement of the mullite crystals upon repeated firing, is most pronounced in kyanite. It is also rather marked in andalusite, especially in the first two firings. It is very small in dumortierite and apparently negligible in sillimanite at the temperatures used.

Given sufficiently high temperatures and enough time, the end product of firing in any of the sillimanite minerals is probably the same, from the standpoint of both mineral composition and specific gravity. The latter approaches the value of 3.031 for pure synthetic mixtures of mullite and silica, in which the oxides are in the ratio of 1:1. This has been shown for andalusite and kyanite, and there appears to be no reason why it should not be true for sillimanite.

For dumortierite, the products of decomposition appear to be similar to those formed from the sillimanite group except that mullite is in higher proportion. The glass may be a borosilicate rather than a silica glass. Dumortierite crystals decompose more readily than crystals of the sillimanite group, but the resulting mullite crystals grow less easily than those formed from the other minerals. This resistance is to be expected when its chemical composition is viewed in the light of the alumina-silica diagram.

With the exception of sillimanite, dissociation of both large and small grains takes place more rapidly than inversion of quartz grains of similar sizes. Based upon the width of the rims of mullite formed around grains of the various minerals as they decomposed during the first firing, andalusite should be ground so that its maximum average grain size does not exceed 0.001 inch in diameter, if it is desired to have all andalusite converted into mullite and glass when fired under the conditions of this investigation. As pointed out, however, there are times when it is an advantage not to have complete dissociation take place in the original firing but to bring it about slowly during use. For such purposes a larger grain size would be necessary. Practically any sized fragment of kyanite or dumortierite would be decomposed under these conditions, and fine grinding would have no effect upon sillimanite.

The foregoing is true when firing takes place in the absence of fluxes. In the presence of fluxes, quite different grain sizes could be used and this maximum probably be safely exceeded, or a corresponding breakdown might be accomplished at a distinctly lower temperature.

No direct or practical quantitative means of measuring rate of reaction is possible except by the width of borders of dissociation products or by the increase in the size of the crystals found. Rates thus determined vary with crystallographic-optical directions. Until values of the heat conductivity of these minerals along various crystallographic or optical directions are available, it is impossible to state whether the faster dissociation of kyanite and dumortierite is due to an inherent quality (for example, generally lower stability) or to lesser heat conductivity of andalusite and sillimanite. The former seems more plausible, although the content of B_2O_3 and H_2O in dumortierite may be a factor in its very low dissociation point. It may be pointed out, however, that kyanite is similar to quartz in that dissociation is aided by shattering of the grain, whereas the other minerals give no indication of this.

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The authors wish to acknowledge their indebtedness to H. F. Royal and A. Rautenberg for firing the samples and for making the specific gravity determinations.

Ceramic Division
Champion Spark Plug Company
Detroit, Mich.

A STUDY OF SOME CERAMIC BODIES CONTAINING TALC*

By Frank F. Fallon

Abstract

Fluxing agents used in most steatite bodies contain alkalis which lower the electrical resistivity of these insulators. Attempts were made to obtain a vitreous steatite composition by additions of oxides containing no alkalis. The effect of grain size, liquids, and varying pressures was determined to obtain the best mixture which would produce the lowest absorption when fired to cone 14, and to this mixture the various oxides were added. The absorption and shrinkages were obtained after firing to cones 13 and 14.

I. Introduction

The work of previous investigators has shown that ceramic compositions consisting mainly of ground talc or steatite (70% or more) have a very narrow firing range when fired to vitrification and that the usual vitrifying agents, such as clays, feldspar, sodium silicate, iron oxide, etc., lower the electrical resistivity as the percentage of these fluxes is increased.

From these facts it was assumed that a method which would allow the percentage of fluxes to be reduced or substituted by more desirable fluxes containing no alkalis would produce a steatite composition of a higher electrical resistivity than the steatite insulators now being used.

To make the pressed pieces as dense as possible in the dry state and thus hasten vitrification on firing and also to lengthen the firing range, various grain sizes of talc were pressed at several pressures to obtain the mixture which would produce the lowest void content in the fired state. To this mixture the various oxides were added in amounts of 5, 10, 15, and 20%, the resultant compositions were fired to cones 13 and 14, and the absorption and shrinkage were obtained for specimens of each heat treatment.

II. Outline of Work

The talc used was extremely pure,[1] comparing closely to the theoretical composition given by Dana's Mineralogy, containing only a trace of iron oxide and about 0.26% lime as neutral silicate. It was pulverized by passing through rolls to prevent obtaining too large a percentage of fines and then screened into the following fractions: (*l*) through a 60-mesh and retained on an 80-mesh screen, (*m*) through an 80-mesh and retained on a 100-mesh screen, (*n*) through 100-mesh and retained on a 200-mesh screen, and (*o*) all through a 200-mesh screen.

Mixtures of these grain sizes of the talc were then pressed at pressures of 1000, 3000, 5000, and 7000 pounds per square inch. In the preliminary work, various liquids (including water, a 50% solution of *N* sodium silicate in water, a saturated solution of gum tragacanth, and a paraffin oil) were added to the finest fraction of talc to ascertain their relative values as lubricants in decreasing the void content of the pressed pieces. The saturated solution of gum tragacanth seemed to be the best lubricant. Its relative value over water, however, was not great enough to warrant its use except at the higher pressures of 5000 and 7000 pounds per square inch, which are higher than commercial practice. The percentage of voids was determined by the usual formula, using a value of 2.7 for the specific gravity of the talc.

The pressed pieces of varying grain sizes were then fired to cone 14 in a gas-fired kiln, and the apparent porosity, percentage absorption, and shrinkage were determined. From these results, it was noted that the mixture of 40% *lm*, 20% *n*, and 40% *o* had the lowest absorption on firing. This was chosen as the mixture to which the fluxing oxides would be added, not only because of the minimum absorption but also because of the ease of producing such a mixture of coarse grains and fines on grinding, as compared to the mixes containing a much larger percentage of coarse grains and which compared favorably with this mixture. Enough fines were present to produce a smooth texture in the fired product.

The fluxing oxides were added as part of the fine portion (−200 mesh) and were distributed thoroughly by wet mixing. The bodies were then dried, pulverized, 3% water added, and formed under 3000 pounds pressure in a hy-

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* Presented at the Annual Meeting, American Ceramic Society, Buffalo, N. Y., February, 1935 (White Wares Division).

[1] Donated by the Sierra Talc Co. of Los Angeles, Calif.

draulic press. The pressed pieces were fired to cones 13 and 14, and the percentage absorption and shrinkages were determined for each heat treatment.

Table I shows that pressures above 3000 pounds per square inch do not decrease the void content enough to warrant these increased pressures, especially where a liquid lubricant is employed, as a small percentage of liquid gives approximately the same void content as increased pressures on the dry mixture.

TABLE III

EFFECT OF THE ADDITION OF VARIOUS OXIDES TO SIERRA TALC OF "DEFINITE GRAIN SIZE" ON THE "PERCENTAGE VOIDS" (UNFIRED)

Addition (%)	Voids (%)	Addition (%)	Voids (%)
20 ZrO_2 dry	12.8	20 ZrO_2–5 B_2O_3 dry	21.2
20 ZrO_2 plastic	18.0	20 ZrO_2–5 B_2O_3 plastic	26.7
15 ZrO_2 dry	14.5	20 TiO_2 dry	22.3
15 ZrO_2 plastic	28.0	20 TiO_2 plastic	26.7
10 ZrO_2 dry	13.5	15 TiO_2 dry	20.8
10 ZrO_2 plastic	23.3	15 TiO_2 plastic	26.7
5 ZrO_2 dry	13.5	10 TiO_2 dry	17.4
5 ZrO_2 plastic	24.6	10 TiO_2 plastic	28.6
15 B_2O_3 dry	15.5	5 B_2O_3 dry	10.2
15 B_2O_3 plastic	31.5	5 B_2O_3 plastic	16.5

TABLE I

EFFECT OF GRAIN SIZE, LIQUIDS, AND PRESSURE ON PERCENTAGE VOIDS (UNFIRED) OF SIERRA TALC MIXTURES

Grain sizing			Pressed	Pressure used (lb./in.²)			
l (%)	*n* (%)	*o* (%)		1000 (%)	3000 (%)	5000 (%)	7000 (%)
100	0	0	Dry	23.0	14.5	12.2	10.1
90	0	10	"	23.0	13.0	9.4	9.2
80	0	20	"	20.2	13.8	11.2	9.5
70	0	30	"	23.4	14.8	11.8	10.0
70	10	20	"	23.0	14.0	11.0	10.0
60	0	40	"	22.7	15.2	12.2	10.8
lm (%)	*n* (%)	*o* (%)					
100	0	0	Dry	22.1	17.8	11.0	9.0
80	10	10	"	22.3	13.4	9.7	9.3
70	10	20	"	23.4	14.3	11.5	10.7
70	10	20	3% water	17.1	11.5	9.3	8.2
70	10	20	5% "	17.9	11.8	11.2	9.6
70	10	20	7% "	15.9	12.0	11.4	11.4
70	10	20	5% gum tragacanth	17.1	10.7	9.3	7.3
70	10	20	7% " "	19.8	13.9	10.0	8.6

NOTE: The symbol, *l*, represents talc screened through a 60-mesh and retained on an 80-mesh; *m*, −80 + 100; *lm*, −60 + 100; *n*, −100 + 200; and *o*, all through 200-mesh.

TABLE II

EFFECT OF GRAIN SIZING AND LIQUIDS ON PRESSED SIERRA TALC MIXTURES FIRED TO CONE 14 (7000 lb./in.²)

Grain Sizing			Pressed	Absorptivity (%)	Apparent porosity (%)	Shrinkage diameter (%)	Length (%)
l (%)	*n* (%)	*o* (%)					
90	0	10	Dry	3.26	8.70	4.2	3.3
80	0	20	"	2.30	8.54	4.6	3.7
70	0	30	"	3.04	8.17	4.6	4.8
60	0	40	"	3.26	8.78	4.6	6.0
80	10	10	"	1.60	4.30	4.6	3.5
70	10	20	"	3.73	10.02	4.2	4.2
60	10	30	"	3.70	7.60	4.2	1.5
50	10	40	"	3.70	10.17	4.2	5.0
lm (%)	*n* (%)	*o* (%)					
100	0	0	"	3.31	8.89	3.7	4.2
80	10	10	"	3.45	9.55	3.9	4.3
70	10	20	"	3.56	9.58	3.90	5.0
70	10	20	3% water	2.93	7.65	3.2	4.2
70	10	20	5% "	3.48	9.50	4.2	4.8
70	10	20	7% "	5.08	13.13	4.6	5.8
60	20	20	Dry	3.38	8.79	3.4	4.1
50	20	30	"	3.23	8.40	3.7	4.6
40	20	40	"	1.39	3.93	6.3	4.7
		100	Dry	4.50	11.25	4.2	4.9
		100	3% water	3.40	8.75	3.9	5.7
		100	5% "	2.63	7.30	5.4	7.3
		100	6% "	6.00	15.47	4.9	6.2
		100	8% "	6.30	16.03	4.9	12.8

TABLE IV

EFFECT OF ADDITION OF VARIOUS OXIDES TO SIERRA TALC OF DEFINITE GRAIN SIZE ON THE ABSORPTION AND SHRINKAGE (FIRED)

	Cone 13			Cone 14		
Addition (%)	Absorptivity (%)	Shrinkage Length (%)	Shrinkage Diameter (%)	Absorptivity (%)	Shrinkage Length (%)	Shrinkage Diameter (%)
20 ZrO_2 dry	9.15	6.76	4.71	8.13	6.57	5.10
20 ZrO_2 plastic	13.16	6.25	5.50			
15 ZrO_2 dry	7.39	3.78	4.05	6.70	6.89	4.30
15 ZrO_2 plastic	13.37	5.49	5.23			
10 ZrO_2 dry	5.41	6.10	4.45	4.61	4.98	4.17
10 ZrO_2 plastic	10.53	5.80	4.58			
5 ZrO_2 dry	5.22	5.28	3.91	2.24	5.35	4.17
5 ZrO_2 plastic	10.53	5.80	4.58			
15 B_2O_3 dry	4.00	8.46	4.05	2.80	5.52	4.04
15 B_2O_3 plastic	13.79	13.7	4.05			
5 B_2O_3 dry	3.13	1.22	3.52	4.49	4.18	3.37
5 B_2O_3 plastic	6.90	3.86	3.25			
20 ZrO_2–5 B_2O_3	10.14	6.16	4.71	8.07	6.55	4.67
20 ZrO_2–5 B_2O_3	14.02	5.36	4.17			
20 TiO_2 dry	5.30	7.51	5.77	6.82	6.40	5.13
20 TiO_2 plastic	6.38	9.52	6.56			
15 TiO_2 dry	4.44	8.32	5.77	4.84	3.66	4.30
15 TiO_2 plastic	6.47	8.45	5.30			
10 TiO_2 dry	3.40	7.15	5.10	4.03	6.85	4.98
10 TiO_2 plastic	6.90	6.50	6.96			
5 TiO_2 dry	3.29	6.53	4.45	3.11	6.35	4.35
5 TiO_2 plastic	5.56	6.99	5.37			

NOTE: Grain sizes were maintained at 40% through 60-mesh and on 100-mesh; 20% through 100-mesh and on 200-mesh, and 40% through a 200-mesh screen. Dry

mixes contained 3% water and the plastic mixes 20% water. All compositions were pressed under 3000 pounds per square inch. The oxides were added as part of the fines (−200 mesh).

III. Summary and Conclusions

(1) For all practical purposes, water seemed to be as good as a saturated solution of gum tragacanth, a 50% solution of *N* sodium silicate in water, or paraffin oil in decreasing the percentage of voids in the pressed unfired talc.

(2) The same approximate void content was obtained in the unfired product by pressing talc containing from 3 to 5% liquid at 3000 pounds per square inch as by pressing dry talc at 7000 pounds per square inch.

(3) The mixture of grain sizes of talc producing the lowest absorptivity when fired to cone 14 is 40% −60 + 100; 20% −100 + 200; and 40% fines −200. This is also the best mixture when considering the ease of producing such a mixture of grains on grinding the talc and the smoothness of the fired piece.

(4) None of the oxide additions investigated decreased absorption of the talc when fired to cone 14. On the contrary, additions over 10% increased the absorption with increasing percentages of added oxides. Since bodies containing TiO_2 are reduced easily, they were very difficult to fire except under extremely oxidizing conditions.

Acknowledgment

The author wishes to thank C. W. Parmelee, Head of the Department of Ceramic Engineering, University of Illinois, for his helpful advice and criticism during the progress of this investigation.

Department of Ceramic Engineering
University of Illinois
Urbana, Illinois

NOTES ON HIGH SPECIFIC GRAVITY SLIPS*

By P. W. Dager

Abstract

A discussion is given of the problem of obtaining the maximum specific gravity of a given slip at a specified viscosity.

I. Introduction

Many questions arise in making a given body into a slip of maximum specific gravity at a specified viscosity. These questions pertain to electrolytes and methods of processing and treating slip. To achieve the maximum specific gravity, it is necessary to study these factors to combine them to the best advantage.

A selection of the most effective electrolyte or combination of electrolytes can be made only by experiment and a process of elimination. A viscosity-percentage electrolyte curve can be made for each electrolyte tried. From these curves, the most likely ones can be chosen and, in turn, can be used in making slip to see what specific gravity can actually be reached and with what ease.

An experiment was made to compare the effect on the viscosity of citric, oxalic, and tannic acids, using a slip which had been reduced to minimum viscosity with potassium hydroxide.[1]

A curve for viscosity as a function of the percentage of electrolyte was obtained for a slip of 1.499 specific gravity, using potassium hydroxide (solution concentration 23.85 grams potassium hydroxide diluted with water to 160 cubic centimeters). It was necessary to use the slip at this specific gravity to obtain viscosity readings because potassium hydroxide alone is not very effective on this body. The minimum on the curve was poorly defined and 0.294% potassium hydroxide was selected as producing the minimum viscosity. This percentage was used in making a slip of 1.694 specific gravity.[2]

II. Viscosity-Percentage Electrolyte

Data for viscosity-percentage electrolyte curves

* Presented at the Annual Meeting, American Ceramic Society, Buffalo, N. Y., February, 1935 (White Wares Division).

[1] The particular body used in all of these experiments contained about 20% clay, the remainder being andalusite and dumortierite.

[2] All viscosity tests were made using a flow viscosimeter described by A. V. Bleininger in *Bur. Stand. Tech. Paper*, No. 51.

were obtained on this slip using citric, oxalic, and tannic acids. The concentrations of the acid solutions were as follows:

100	grams	citric	acid	diluted	with	water	to 160 cc.
30	"	oxalic	"	"	"	"	" 165 cc.
80	"	tannic	"	"	"	"	" 160 cc.

The curves show that the minimum viscosity reached with each acid is about the same. Only the citric acid curve gives a well-defined minimum. The tannic acid curve is comparatively irregular, and the oxalic acid curve has a long range at minimum viscosity.

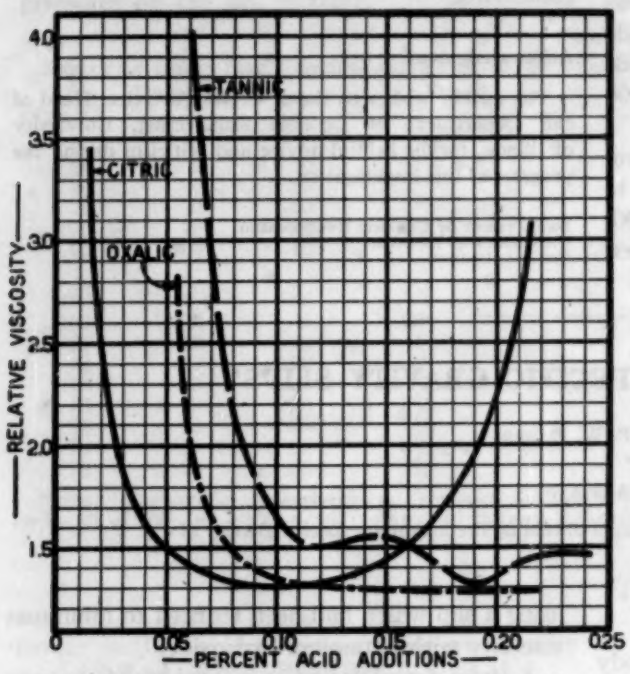

FIG. 1.—The effect of additions of citric, oxalic, and tannic acids on slip containing 0.294% potassium hydroxide.

III. Percentage Electrolyte-Viscosity-Specific Gravity

Another experiment was made to determine the difference in percentage of electrolyte required to reach minimum viscosity of slip at different specific gravities. A batch of slip of 1.75 specific gravity was prepared and divided into four portions. One portion was left unchanged, and the others were reduced by water to 1.70, 1.65, and 1.60, respectively. Viscosity-percentage electrolyte curves were obtained for each, using sodium silicate of brand N.

It is obvious that the percentage electrolyte (on the dry weight basis) required to reach minimum viscosity would be less for low specific gravity slip than for high specific gravity slip. This relation of the percentage electrolyte to the specific gravity can be taken from the curves.

IV. Effect of Different Methods of Slipmaking

There are a number of ways that slips can be made. Whether or not the use of raw materials, filter-press cake, or pugged body will help in obtaining slip of the highest specific gravity has been dealt with by Schramm and Hall.[3] They found that slip made from pugged body at any given specific gravity was less viscous than slip made from filter-press cake, and they state that it is more difficult to make slip from raw material than from filter-press cake. Their conclusions are confirmed in an experiment to compare the viscosities of slips made by using (*a*) a body containing 8% moisture, (*b*) filter-press cake, and (*c*) pugged body. A sample of the partially dry body was divided into three parts. One-third was made into slip, filter-pressed, and pugged; another was made into slip and filter-pressed. Each part was made into a slip of specific gravity 1.905 using water and an equal percentage of electrolyte. The relative viscosities[4] of the three slips were as follows: slip from body containing 8% moisture, 5.64; slip from filter-press cakes, 2.56; and slip from pugged body, 2.05. The use of pugged body in making slip to a high specific gravity is a decided advantage with this clay-andalusite-dumortierite body.

V. Effect of Water Removal

The conventional manner of making slip is to blunge the body with the proper amount of water to obtain the desired specific gravity. An experiment was performed to see if making slip with an excess of water and removing the excess would make a higher specific gravity possible by giving a lower viscosity. Two slips were made using the same percentage of electrolyte, but one contained twice as much water as the other. The specific gravities of the respective slips were 1.60

[3] E. Schramm and F. P. Hall, "Notes on Casting Slip," *Jour. Amer. Ceram. Soc.*, **17** [9] 262–67 (1934).

[4] A $^{9}/_{32}$-inch orifice was used on the viscosimeter for these tests.

and 1.393. Sufficient water was removed from the low specific gravity slip by decanting and filtering to raise the specific gravity to 1.60. The relative viscosity of the slip made with the correct amount of water was 1.70; that of the slip with excess water was 1.61. The test was repeated with slip of 1.67 specific gravity. The excess water was removed from the low specific gravity slip by evaporation. The relative viscosity of the slip made with the correct amount of water was 2.44; that of the slip made with excess water was 2.38. A decided coagulation or jelling was noticed in the slip from which the excess water had been evaporated. Jelling had also been noted in slips which contained more electrolyte than was required to bring them to minimum viscosity. The slips were very fluid while being agitated, but on standing for sometimes less than one minute they would coagulate so that they could not be poured.

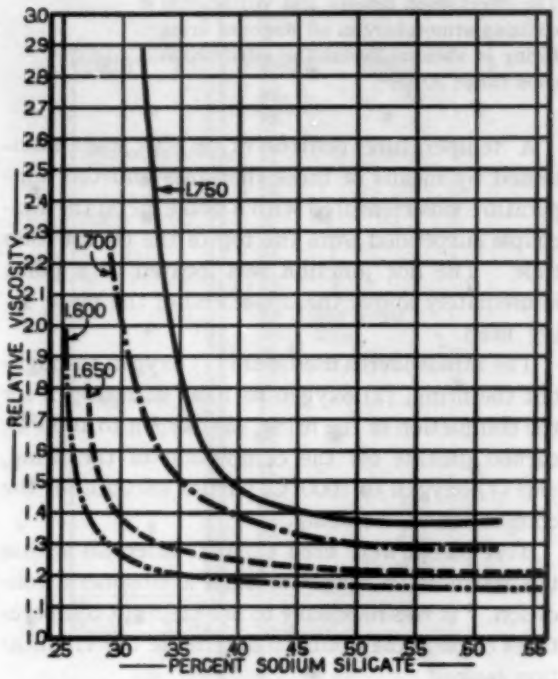

FIG. 2.—The effect of sodium silicate on slip at different specific gravities.

The excess water was removed from one slip by partial drying in a plaster mold. The viscosity became so great before a specific gravity of 1.67 was reached that viscosity readings could not be taken.[5]

VI. Effect of Vacuum Treatment

Some simple tests were made to determine the effect of vacuum treatment on the viscosity of the slip. Work on this subject has been done by Bleininger[2] and by Kraner and Fessler.[6]

A cylindrical chamber, 12 inches in diameter and 12 inches deep, was evacuated to 27 inches vacuum. Slip was introduced slowly into the chamber by a funnel and allowed to drop to the bottom of the chamber. The results are given in the following table:

Slip			After Vacuum		
Specific gravity	Relative viscosity	Temperature (°F)	Specific gravity	Relative viscosity	Temperature (°F)
1.386	2.07	79	1.386	2.1	70 (no electrolyte)
1.413	2.83	71	1.410	2.84	70 (no electrolyte)
1.701	3.0	75	1.705	3.57	70 (electrolyte)
1.709	2.51		1.708	2.44	(electrolyte)

Acknowledgment

The writer acknowledges his indebtedness to Edwin Horvath for assistance in carrying on this work.

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DETROIT, MICHIGAN

[5] Points on clay bodies in contact with plaster have been brought out by Webb. See H. W. Webb, "Alkaline Casting Slip," *Trans. Ceram. Soc.* [Eng.], 33 [4] 129 (1933).

[6] H. M. Kraner and A. H. Fessler, "Vacuum Treatment of Clay Slips and Bodies," *Jour. Amer. Ceram. Soc.*, 11 [11] 769 (1928).

EFFECT OF FURNACE ATMOSPHERE AND PARTIAL VACUUM UPON THE VITRIFICATION OF A HIGH MULLITE PORCELAIN*

By A. M. Hossenlopp and R. Russell, Jr.

Abstract

A high mullite porcelain body was fired in various atmospheres and in vacuum. O_2, CO_2, and N_2 atmospheres and vacuum were used separately for the firing, preceded by an oxidizing atmosphere up to 1000°C. The effect upon density and vitrification temperature and range was determined. An oxidizing atmosphere in all stages of firing is advantageous in obtaining high density. Firing in vacuum lowers the vitrification temperature 100°C and increases the vitrification range 20°C.

I. Introduction

The purpose of this research was to determine the effect produced by various atmospheric conditions during firing upon the apparent specific gravity, vitrification range, and temperature of a high mullite porcelain.[1] The various atmospheric conditions were obtained by introducing the gases O_2, N_2, and CO_2 and by using a partial vacuum. The gases selected are present in the atmospheres usually prevailing in ceramic kilns.

II. Procedure

The porcelain was fired in a platinum-wound resistance furnace of the vertical type (Fig. 1). The combustion chamber was a fused silica tube and the gas was introduced through a glass tube cemented into the bottom. A rubber hose connected the glass tube to a gas-control valve supplying a standard purity of gas.[2]

To attain partial vacuum, the entire furnace was placed within a steel drum which could be sealed air-tight. The evacuation of the drum to an absolute pressure of 0.3 inch mercury (±0.1 inch) required about 5 minutes.

The test pieces were truncated cones, $^5/_8$ inch high, with end diameters of $^1/_4$ and $^1/_2$ inch, and each piece had a 0.1-inch hole through the longitudinal center. A piece was suspended within the furnace by a platinum wire of such length as to locate the piece within the maximum temperature zone. The location of this zone was checked at regular intervals.

A temperature control of ±2°C was maintained by means of three rheostats and the temperature was measured with a noble metal thermocouple suspended from the top of the combustion tube. The hot junction was located at a point immediately above the upper end of the piece being fired.

The atmospheres used were (1) oxygen throughout the firing, (2) oxygen to 1000°C, nitrogen for the completion of the firing, (3) oxygen to 1000°C, carbon dioxide for the completion of the firing, and (4) oxygen to 1000°C, partial vacuum for the completion of the firing.

Test pieces were fired at 10°C intervals within the vitrification range for each atmospheric condition. It was necessary to fire pieces at temperatures outside the limits to determine the vitrification range.

The following procedure was adopted for firing a test piece: Having located the test piece and thermocouple within the furnace, gas was admitted at the rate of 80 liters per hour and regulated by a diaphragm valve. This valve was adjusted according to the pressure recorded on an inclined manometer previously calibrated by a standard gas flowmeter.

A 5-minute period was allowed to clear the combustion chamber of atmospheric air before the firing was begun. In a typical test, the temperature was raised to 1000°C in 3 hours and then to 1350°C in $2^1/_2$ hours. This maximum temperature was maintained for one hour. The gas continued to pass through the furnace for 30 minutes after the cooling period began in order to allow the porcelain to cool to 1000°C before coming in contact with atmospheric air.

Each fired piece was tested for apparent specific gravity and absorptivity. The apparent specific gravity determinations were made according to the standard test method with an

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[1] For previous investigation see A. E. Badger, "Effect of Various Gaseous Atmospheres on the Vitrification of Ceramic Bodies," *Jour. Amer. Ceram. Soc.*, **16** [2] 107–17 (1933).

[2] Tanks furnished by the Air Reduction Sales Corporation.

analytical balance accurate to 0.001 gram. Each apparent specific gravity recorded is the average for two test pieces fired individually but under similar conditions. Absorptivity was detemined by immersing the test pieces for one hour in an aniline dye solution under 2000 pounds per square inch pressure.

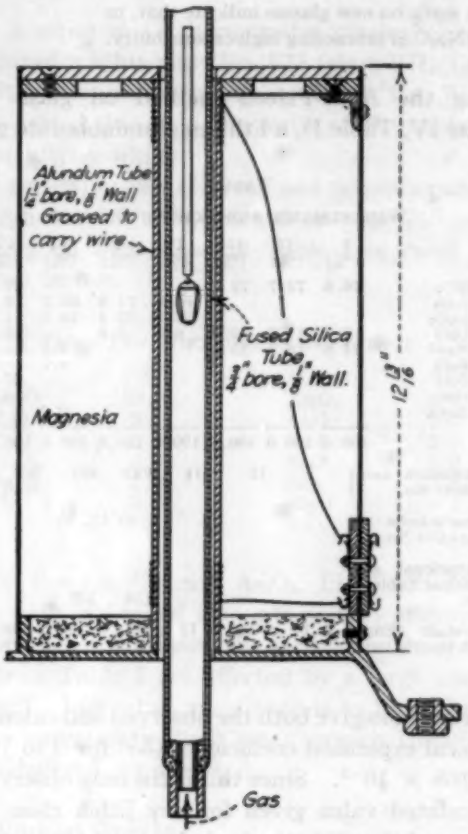

FIG. 1.

III. Results

The values obtained are presented in Table I and in Fig. 2. The presence of an oxygen atmosphere through the entire firing period was advantageous in attaining a high apparent specific gravity. The maximum apparent specific gravity obtained by the substitution of a neutral atmosphere (nitrogen or carbon dioxide), or partial vacuum above 1000° C, was approximately the same in all three cases. However, while the substitution of nitrogen or carbon dioxide for oxygen lowered the maturing temperature approximately 30°, it was reduced approximately 100° by the substitution of partial vacuum.

TABLE I

Atmospheric conditions	Minimum vitrification temperature(°C)	Vitrification range(°C)	Temperature of maximum apparent specific gravity (°C)
O_2	1380	70	1420
O_2 to 1000°C, N_2 to end	1350	50	1390
O_2 to 1000°C, CO_2 to end	1360	60	1390
O_2 to 1000°C, Vacuum to end	1260	90	1320

The substitution of a neutral atmosphere for an oxidizing atmosphere above 1000° shortened the vitrification range 10 to 20°, while the substitution of partial vacuum lengthened it 20°.

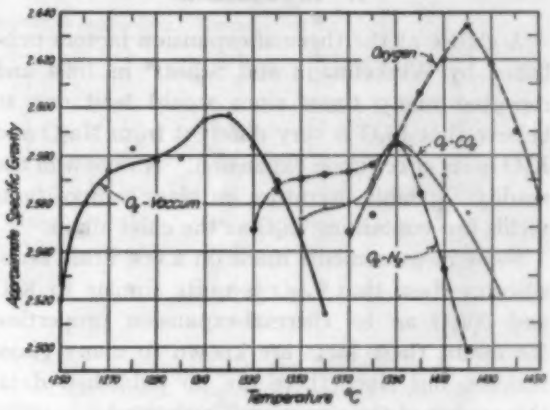

FIG. 2.

IV. Conclusions

The following general tendencies are indicated in firing a high mullite porcelain under various atmospheric conditions:

(1) A neutral atmosphere during vitrification as compared to an oxidizing atmosphere decreases the apparent specific gravity, lowers the vitrification temperature, and shortens the vitrification range.

(2) A partial vacuum during vitrification as compared to an oxidizing atmosphere under atmospheric pressure decreases the apparent specific gravity, lowers the vitrification temperature, and lengthens the vitrification range.

Since furnace atmosphere during the vitrification of a high mullite porcelain exerts a marked influence upon the vitrification temperature and range as well as on the apparent specific gravity of the fired ware, the proper control of furnace atmosphere is necessary in the production of a uniformly high quality porcelain.

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LITHIUM OXIDE AS A CONSTITUENT OF GLASSES—ITS EFFECT ON THERMAL EXPANSION*

By Louis Navias

Abstract

Winkelmann and Schott give the factors of 10.0 to Na_2O, 8.5 to K_2O, and 2.0 to Li_2O to indicate the effect of these oxides upon thermal expansion. A review of the literature of glasses containing Li_2O and some measurements made on new glasses indicate that, in respect to thermal expansion, Li_2O is as effective as Na_2O in promoting high expansibility.

I. Introduction

A glance at the thermal-expansion factors published by Winkelmann and Schott[1] in 1894 and repeated many times since would lead one to believe that Li_2O is very different from Na_2O and K_2O in its effect upon expansion. A review of the readily available literature on glass compositions yields few containing Li_2O as the chief alkali.

Some measurements made on a few lithia borosilicates show that Li_2O is quite similar to K_2O and Na_2O as to thermal-expansion properties. No doubt these facts are known to many glassmakers, but since there are no published data, this review of the situation is presented.

II. Historical

(1) Work of Schott and Co-Workers

Hovestadt[2] in his book on Jena glass quotes extensively from Schott's work,[3] describing Li_2O as a component of glasses. The recipes, oxide compositions, and molecular proportions are given. In glass I there is a serious error of calculation, in glass II no error, in glass III a minor error. The compositions in Table I are calculated from the recipe compositions. Abbé measured the optical constants of these "lithium crown" glasses, which are silicates.

Winkelmann and Schott[1] in their 1894 paper refer to Schott's earlier paper in 1892 and summarize their findings "über thermische Widerstandscoefficienten" as a function of glass composition. Of interest here is the measurement by Weidmann using the Abbé-Fizeau method on glass W43 (glass IV, Table I), a lithium aluminoborate glass.

Table I

Winkelmann and Schott Glasses

	I (%)	II (%)	III (%)	IV (%)	V (%)	VI (%)	VII (%)
SiO_2	76.8	73.7	72.7				51.0
B_2O_3				64.0	71.8	69.1	9.3
Al_2O_3				30.0	22.4	18.0	1.8
Li_2O	8.7	11.1	12.3	6.0	5.8		6.5
Na_2O	14.5	15.2	15.1			8.0	
BaO						4.7	
ZnO							27.7
PbO							3.7
As_2O_3						0.2	
	100.0	100.0	100.1	100.0	100.0	100.0	100.0
Winkelmann and Schott No.	I	II	III	W43	W1	W2 W45	VII
Glastechnische Tabellen No.				IX, 39	IX, 38		
International Critical Tables No.				136	137		
Hovestadt (English translation)	p. 11	p. 12	p. 12	p. 146 p. 216	p. 146	p. 146 p. 216	p. 244 304 309

The authors give both the observed and calculated cubical expansion coefficients (3α) for 0 to 100°C as 168×10^{-7}. Since this is the only observed or calculated value given for any lithia glass, it is assumed that it is the basis for the Li_2O factor, as follows:

	W43 (a borate glass)	
B_2O_3	64% × 0.1 =	6.4×10^{-7}
Al_2O_3	30% × 5.0 =	150.0
Li_2O	6% × 2.0 =	12.0
	100%	168.4

Another glass similar to W43 is W1 (glass V, Table I) with lower Al_2O_3. These two glasses are listed among 72 different glasses investigated by Winkelmann and Schott for numerous physical properties and are listed by International Critical Tables and by Glastechnische Tabellen.

A soda glass of somewhat similar type, W2 (glass VI, Table I) measured by Pulfrich over the range 14.4 to 94.4°C, gives for the cubical thermal expansion coefficient 3α---202 × 10^{-7}. Using Winkelmann and Schott's factors with Na_2O as

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* Presented at the Annual Meeting, American Ceramic Society, Buffalo, N. Y., February, 1935 (Glass Division).

[1] A. Winkelmann and O. Schott, "Über thermische Widerstandscoefficienten verschiedener Gläser in ihrer Abhängigkeit von der chemischen Zusammensetzung," *Ann. Phys. Chem.*, **51**, 730–46 (1894).

[2] H. Hovestadt, Jena Glass (English tr. by Everett and Everett, 1902).

[3] O. Schott, Verhandl. Vereins. z. Beförderung des Gewerbefleisses, 1882.

10.0, the calculated expansion is 191×10^{-7}. On the basis of these similar borates the conclusion can be reached that for a 1% change in alkali (factor for Li_2O 2.0), Li_2O is only one-fifth as effective in changing thermal expansion as $Na_2O\cdot\left(\frac{Li_2O}{Na_2O} = \frac{2.0}{10.0} = 0.2\right)$.

In a series of 17 thermometer glasses, Schott[4] developed a lithia glass No. VII (glass VII, Table I) with a depression constant of 0.10°C. Weidmann tested this glass in a series of 13 glasses for elastic after-working.[4]

In reviewing Winkelmann and Schott's paper,[1] a significant sentence is found on page 736 commenting on their classical Table I of cubic expansion factors.

TABLE I OF WINKELMANN AND SCHOTT

	×10		×10
Na_2O	10.0	As_2O_3	2.0
K_2O	8.5	Li_2O	2.0
CaO	5.0	P_2O_5	2.0
Al_2O_3	5.0	ZnO	1.8
BaO	3.0	SiO_2	0.8
PbO	3.0	MgO	0.1
		B_2O_3	0.1

"Since the constituents As_2O_3, Li_2O, and MgO occur only in limited amounts or only seldom in the investigated glasses, the factors for these materials in Table I are affected by a large uncertainty." Just what magnitude is to be assigned to the uncertainty, "mit einer grossen Unsicherheit behaftet," is not stated.

(2) Work of Grenet

Soon after Schott's publication of the statement that the thermal expansion of a glass is an additive function of the oxides present in the glass, Grenet in France tested this statement on some simple silicates and borates.

(*a*) *Borates.*—In his first paper (1896), Grenet[5] lists lithium, sodium, and lead borates with their thermal expansions determined between 18°C and 100°C by the Fizeau method. The oxides are given in their molecular proportions as $NaO\cdot 2BoO_3$, $LiO\cdot 5BoO_3$, and $PbO\cdot BoO_3$, etc. In converting molecular proportions to percentage weight compositions it matters greatly if the formula is considered as NaO instead of Na_2O. From a subsequent paper of Grenet's, however, in which the same molecular proportions are given with their corresponding weight compositions, there is no doubt but that the oxide molecules were considered Na_2O, Li_2O, and B_2O_3. The data as submitted by Grenet[5] are given in Table II with the oxides as Na_2O, etc.

TABLE II

BORATE GLASSES OF GRENET*

Molecular proportions		Weight Compositions (%)†		Coefficient linear thermal expansion 18–100°C
Na_2O	B_2O_3	Na_2O	B_2O_3	
1	2	30.8	69.2	953×10^{-8}
1	2.5	26.3	73.7	704
1	5.13	14.8	85.2	817
1	10.18	8.1	91.9	933
1	16.83	5.0	95.0	1019
	B_2O_3		100.0	1414
Li_2O	B_2O_3	Li_2O	B_2O_3	
1	3	12.5	87.5	678×10^{-8}
1	4	9.7	90.2	590
1	5	7.9	92.1	646
1	10	4.1	95.9	900
	B_2O_3		100.0	1414

* L. Grenet, *Compt. rend.*, **123**, 891–93 (1896).

† All percentage weight compositions are the calculations of the writer. They are not given in the paper of Grenet.

The percentage weight compositions are those of the writer. From the data Grenet concludes that for the borates the expansion functions of the oxides are not uniformly additive.

In 1897, Grenet[6] published a long paper giving details of his researches on glasses. This paper includes also the sodium, lithium, and lead borates of the previous year. This time his Table II is quite complete with molecular equivalents, percentage weight compositions, percentage volume compositions, and the thermal expansion. While the oxides are written NaO, LiO, and BoO_3 they are calculated as Na_2O, Li_2O, and B_2O_3. Unfortunately, while the lithium-borate series has the same molecular proportions in both papers, the thermal expansion values in the second paper are higher in each case. In the sodium-borate series conditions are much worse, for not only are the later expansion values higher, but two of the molecular proportions do not agree with Grenet's own percentage weight compositions. Fortunately there are curves plotted with each point definitely marked for chemical composition (his calculated volume composition) and thermal

[4] In Hovestadt, Jena Glass, p. 244 and pp. 304–10.

[5] L. Grenet, "The Rôle of Boric Acid in Glasses and Enamels," *Compt. rend.*, **123**, 891–93 (1896).

[6] L. Grenet, "Recherches expérimentales sur les Verres," *Bull. soc. encour. ind. nat.*, **96**, 772–806 (1897).

expansion. Hence it is possible to check back and show that glass $1Na_2O \cdot 4B_2O_3$ does not correspond to 14.7% Na_2O as given in 1897 but that it is really $1Na_2O \cdot 5.13B_2O_3$ as given in the 1896 paper. These points are important, historically, because Le Chatelier[7] quotes Grenet's data of 1897 on lead borates and sodium borates with all the errors, and Glastechnische Tabellen[8] quote Le Chatelier continuing the errors. Table III gives the formulas and computations for Grenet's 1897 paper, from which the expansion data are also taken. Comparing Tables II and III, it will be noticed that while the later values are higher, they are not uniformly higher.

TABLE III

BORATE GLASSES OF GRENET*

Molecular proportions		Weight compositions (%)		Coefficient of linear thermal expansion 18–100°C
Na_2O	B_2O_3	Na_2O	B_2O_3	
1	2	30.7	69.3	1119×10^{-8}
(1	3)†	28.6	71.4	942
(1	4)†	14.7	85.3	876
1	5.13**	14.7	85.3**	850**
1	10.18	8.0	92.0	967
1	16.83	5.0	95.0	1050
	B_2O_3		100.0	1446
Li_2O	B_2O_3	Li_2O	B_2O_3	
1	3	12.5	87.5	710×10^{-8}
1	4	9.7	90.2	622
1	5	7.9	92.1	678
1	10	4.1	95.9	934
	B_2O_3		100.0	1446

* L. Grenet, see footnote 6.

† These molecular proportions do not correspond to percentage weight compositions.

** This composition is not found in Grenet's Table II but it is found on his curve.

Taking a factor of 0.1 for B_2O_3, according to Winkelmann and Schott, and comparing the 8% alkali glasses and the 4 to 5% alkali glasses, using the determined expansions of Grenet, it is possible to make a fairly direct comparison between Li_2O and Na_2O. For the 8% alkali borates the ratio of the factors becomes

$$\frac{Li_2O}{Na_2O} = \frac{24.5}{35.1} = 0.70.$$

For the 4 to 5% alkali borates, the ratio of factors becomes

$$\frac{Li_2O}{Na_2O} = \frac{66.0}{61.1} = 1.08.$$

Here the 1897 data have been given. For the 1896 data, the ratio is changed slightly to 0.69 and 1.07. The conclusion to be drawn is that in such borates Li_2O is in the same class as Na_2O in its effect on thermal expansion.

(*b*) *Silicates.*—In the same paper of 1897,[6] Grenet gives corresponding thermal-expansion coefficients and compositions for simple sodium, potassium, lead, and lithium silicates. Although the lithium silicates are measured, the notations follow each of the glasses: Li_2O 20.0% slightly devitrified, 11.1% distinctly devitrified, and 7.7% distinctly devitrified.

Grenet[6] also added alkalis and other substances to a St. Gobain plate glass and a Blanzy bottle glass, measuring the thermal expansion between 18°C and 100°C. Table IV gives the compositions of interest here. The ratios of the increases in expansion for Li_2O/Na_2O are 0.78 and 1.25 and indicate merely that Li_2O and Na_2O have similar effects on the expansion of such silicate glasses.

TABLE IV

GRENET'S GLASSES

St. Gobain plate glass (%)	Alkali (%)	$\alpha \times 10^8$	Blanzy bottle glass (%)	Alkali (%)	$\alpha \times 10^8$
100		819	100		696
94	6 Na_2O	916	98	2 Na_2O	744
94	6 K_2O	883	98	2 Li_2O	756
94	6 Li_2O	895	96	4 K_2O	708
Increase in expansion due to alkali addition			Increase in expansion due to alkali addition		
6% Na_2O		97	2% Na_2O		48
6% Li_2O		76	2% Li_2O		60

Ratio $\frac{Li_2O}{Na_2O} = \frac{76}{97} = 0.78$ Ratio $\frac{Li_2O}{Na_2O} = \frac{60}{48} = 1.25$

(*c*) *Other Lithia Glasses.*—In Table V are given the compositions of several glasses containing appreciable amounts of Li_2O with the sources of information. Damour and Thuret[9] measured the annealing range. Ziegler and Wellmann[10] measured the ultra-violet transmission of a borate glass.

Preston and Turner[11] made a series of 13 glasses between 10% and 50% Li_2O by weight, the remainder being SiO_2, and measured the volatilization of the Li_2O. They concluded that for glasses

[7] H. Le Chatelier, La Silice et Les Silicates, p. 329 (1914).

[8] Glastechnische Tabellen, pp. 232–33 (1932).

[9] Damour and Thuret quoted in Glastechnische Tabellen, p. 694.

[10] W. Ziegler and M. Wellmann, "Über ultraviolettdurch lässige Alkali-Beryllium—Boratgläser," *Z. tech. Physik*, **7**, 288-89 (1933).

[11] Eric Preston and W. E. S. Turner, "Volatilization of Lithium Oxide at High Temperatures from Lithium Oxide-Silica Glasses," *Jour. Soc. Glass Tech.*, **18**, 143–68 (1934).

TABLE V

Damour and Thuret* (%)		Ziegler and Wellmann† Ultra-violet transmitting glass (%)	
SiO_2	55.12		
Na_2O	15.85		
Li_2O	7.35	Li_2O	13.6
CaO	7.72	BeO	4.4
B_2O_3	13.78	B_2O_3	82.0
	99.82		100.0

* Glastechnische Tabellen, p. 694.
† *Z. tech. Physik*, 7, 288–89 (1933).

containing about 20 molecular per cent of the oxides K_2O, Na_2O, or Li_2O, these constituents were almost equally volatile at 1400°C.

without becoming opaque. The same results were obtained from melts made either with Al_2O_3 or $Al(NO_3)_3$, $9H_2O$, $B(OH)_3$, and Li_2CO_3 of high purity.

As indicated in section II(1), the writer believes that glass W43 is the only composition on which Winkelmann and Schott based their calculations in determining the expansion factor for Li_2O.

(*b*) *W1* (*Table I, No. V*).—Clear glasses as 20-gram melts in platinum were readily made of this composition, B_2O_3 72%, Al_2O_3 22%, Li_2O 6% using $B(OH)_3$, Al_2O_3 or $Al(NO_3)_3 9H_2O$, and Li_2CO_3. This glass can be worked to some extent before the lamp without devitrifying. By comparing

TABLE VI

Glass No.		Calculated weight compositions (%) 250	251	252	254	Actual chemical analyses (%) 184*	244†
SiO_2		70.0	70.0	75.0	75.0	65.32	66.9
B_2O_3		18.0	18.0	13.0	13.0	22.57	(19.0)
Al_2O_3		5.0	5.0	5.0	5.0	5.49	7.5
Na_2O			3.0	3.0		6.71	
Li_2O		7.0	4.0	4.0	7.0		6.7
		100.0	100.0	100.0	100.0	100.09	100.1
Coefficient of linear thermal expansion	25°–100°C	5.07	5.07	4.93	Clear in pot; frosts on working in flame	5.07	5.07 × 10^{-6}
	25°–200	5.10	5.08	4.99		5.07	5.18
	25°–300	5.18	5.11	5.04		5.12	5.25
	25°–400	5.36	5.27	5.14		5.18	5.35
	25°–500	6.72	6.97	6.62		6.36	7.07
Calculations							
(a) Hall's factors; measured coefficient of expansion between 25° and 400°C							
Calculated factor for Li_2O		329	337	361			314
Calculated factor for Na_2O			(287)	(287)		287	
(b) Winkelmann and Schott's factors; measured coefficient of expansion between 25° and 100°C							
Calculated factor for Li_2O		9.9	9.5	7.7			8.8
Calculated factor for Na_2O			(10.4)	(10.4)		10.4	

* Chemical analysis made by W. C. Taylor, Corning Glass Works.
† Chemical analysis by G. E. Co. Testing Laboratory in duplicate; B_2O_3 by difference.

No doubt other lithia glasses have been recorded in the technical and patent literature.

III. Present Work

(1) Repeating Schott's Glasses (Borates)

(*a*) *W43* (*Table I, No. IV*).—Attempts to make this glass, B_2O_3 64%, Al_2O_3 30%, Li_2O 6%, as 20-gram melts and 200-gram melts in platinum are successful when care is taken not to heat too rapidly or too strongly. Otherwise crystallization sets in, due probably to the loss of Li_2O and B_2O_3, thereby increasing the Al_2O_3 content.

The clear glass can not be heated in the flame

W1 with W43, it is seen that W1 has 8% less Al_2O_3 and 8% more B_2O_3, enabling the maintenance of the vitreous state.

(2) Borosilicate Glasses

In Table VI are given the results on a few borosilicate glasses containing Li_2O and Na_2O. The glasses were melted in platinum, using high-grade chemicals, yielding 800-gram melts. Two glasses were analyzed for direct comparison, namely No. 184 with 6.71% Na_2O and No. 244 with 6.7% Li_2O. The other four glasses are given as calculated percentage weight compositions.

The thermal expansions were measured by

Burger[12] of this laboratory on 12-inch annealed rods, comparison being made with rods of molybdenum. The calculated coefficients of linear thermal expansion between 25°C and 500°C are given in five intervals of temperature.

For calculating the expansion factors, two sets of data were used. Hall[13] has developed a set of linear expansion factors intended to cover a wide range of temperature. In Table VI, the determined linear expansions for the interval 25 to 400°C have been used. Over this range the expansions of these glasses vary rather uniformly with temperature.

In No. 184 glass, using 5.18×10^{-6} as the coefficient of linear expansion (25 to 400°C) and Hall's factors for SiO_2, B_2O_3, and Al_2O_3, the factor for Na_2O is calculated as 287. In glass No. 244, using the coefficient of linear expansion (25 to 400°) 5.35×10^{-6} and the same factors of Hall, the factor for Li_2O is calculated as 314. Hence for these two similar glasses with identical alkali content, the factor ratio of

$$\frac{Li_2O}{Na_2O} = \frac{314}{287} = 1.10.$$

In glass No. 250, the factor for Li_2O appears as 329. In glasses No. 251 and No. 252, containing both Na_2O and Li_2O, the factor 287 for Na_2O (as found from No. 184 glass) is used, and the Li_2O factors are calculated as 337 and 361. For these three glasses, the factor ratios Li_2O/Na_2O are 1.15, 1.17, and 1.25. While the individual factors are not very significant, the factor ratios are quite significant, indicating that Li_2O in such glasses is quantitatively as effective as Na_2O in promoting high thermal expansion.

Similar calculations were made using Winkelmann and Schott's factors for SiO_2, B_2O_3, and Al_2O_3, and the determined thermal-expansion data over the range 25° to 100°C. The factor for Na_2O in No. 184 glass is found to be 10.4 ($3\alpha \times 10^7$) and for Li_2O in No. 244 glass, 8.8. The factor ratio

$$\frac{Li_2O}{Na_2O} = \frac{8.8}{10.4} = 0.85$$

For glass No. 250, the Li_2O factor becomes 9.9. In glasses No. 251 and No. 252, the Na_2O factor is maintained at 10.4 and the Li_2O factors are calculated as 9.5 and 7.7. For these three glasses, the factor ratios Li_2O/Na_2O are 0.95, 0.91, and 0.74. Here the conclusion can be reached that Li_2O is nearly as effective as Na_2O in promoting thermal expansion.

IV. General Conclusions

(1) A review of the literature shows that Winkelmann and Schott based their calculations for the expansion factor of Li_2O on one composition, namely, W43, Li_2O 6.0, Al_2O_3 30.0, B_2O_3 64%.

(2) From the literature, several borate glasses have been taken and, by comparison of thermal expansions, it has been shown by calculation that Na_2O and Li_2O are similar in behavior in promoting high thermal expansions.

(3) The same conclusion as in (2) is drawn for silicate glasses taken from the literature.

(4) Several borosilicate glasses containing Li_2O and Na_2O have been made and their expansions measured. The calculated factors for Li_2O and Na_2O in these glasses show that Li_2O is as effective as Na_2O in imparting a high thermal expansion to glasses containing it.

NOTE: Since the presentation of this paper, there has appeared an excellent paper by S. C. Waterton and W. E. S. Turner on "Some Properties of Mixed Alkali-Lime-Silica Glasses Containing Lithia, Soda, Potash, and Rubidia," *Jour. Soc. Glass Tech.*, **18**, 268–85 (1934). The thermal expansions of glasses of the composition SiO_2 75%, CaO 10%, R_2O 15% were measured. Using factors of linear thermal expansion SiO_2 0.05×10^{-7} and Na_2O 4.18×10^{-7}, they calculate, for the range 0 to 160°C, factors as follows: Li_2O 4.9, K_2O 3.4, Rb_2O 2.6×10^{-7}. The ratio of factors $\frac{Li_2O}{Na_2O} = \frac{4.9}{4.18} = 1.17$ shows that in this type of glass Li_2O causes a greater thermal expansion than Na_2O for equal weight percentage present in the glass.

RESEARCH LABORATORY
GENERAL ELECTRIC COMPANY
SCHENECTADY, NEW YORK

[12] E. E. Burger, "Expansion Characteristics of Some Common Glasses and Metals," *Gen. Elec. Rev.*, **37** [2] 93–96 (1934); *Ceram Abs.*, **13** [10] 253 (1934).

[13] F. P. Hall, "Influence of Chemical Composition on Physical Properties of Glazes," *Jour. Amer. Ceram. Soc.*, **13** [3] 182–99 (1930).

INVESTIGATION OF GLASSHOUSE SUPERSTRUCTURE MATERIALS*

By W. L. Fabianic

Abstract

A practical investigation was conducted on the selection of those refractories most suitable for use in glass-furnace port jambs, port sills, port floors, baffles, port-nozzle side walls, port side walls proper, and top checker courses. These refractories are exposed to the destroying action of a viscous high-temperature basic slag and batch dust of a given composition. Over one hundred various brands of brick were tested, ranging in composition from a first-grade fire brick to super-refractories of the 80% alumina class. The mechanical, chemical, physical, and mineralogical properties of these brick were studied. The results of the test determinations were checked by making actual service installations in operating furnaces. The performance of the refractories in these installations after ten months of service verified the test results to a remarkable degree. The mineralogical relationship of the minerals in the refractory as received was found to be of more importance than chemical or physical properties. A tentative method of determining the suitability of a brick for actual service by combining petrographic inspection with physical properties is suggested.

I. Introduction

The ever-increasing production rate of the past few years has resulted in an increase in tonnage pull of glassmelting furnaces. Rates of 12 to 20 square feet of furnace area per ton of glass melted per day are no longer satisfactory. The rate now is frequently 6 to 9 square feet per ton. This means more batch to be fed, increased batch dust, alkali vapors, and higher temperatures for melting. The result is a much more severe attack on all the refractories but chiefly on the superstructure refractories, particularly toward the charging end of the furnace where heat, dust, and alkali vapors are most severe. The result has been a rapid failure in the rear ports of sills, jambs, port-nozzle walls, breast walls, tuck stones, invert arches, burner port block, and top checker courses. These are superstructure failures rather than flux block failures.

This paper is a description of a successful method of designating what refractory should be chosen for the vulnerable locations in the furnace. Proper methods are given for selecting refractories for (1) breast walls, port-nozzle side walls, and baffle walls, and (2) for port walls proper and top checker courses.

A bibliography of the most important work done on this subject is appended.

II. Presentation of Problems

The first problem was to find a brick that would hold up in the last three or four ports on both sides of the furnace toward the charging end. These refractories, including port-nozzle side walls, port floors, breast walls, baffle walls, and burner port blocks, were exposed to the same service conditions, and consequently the same type of refractory was needed for all of the locations. Silica refractory, formerly used, would no longer withstand the increased temperature, dust, and alkali vapors. A refractory that would stand the high-velocity furnace flames and gases heavily laden with batch dust and alkali vapors at a constant temperature of over 2750°F was needed.

The batch dust fused with the refractories, forming a viscous slag, the outside layer of which analyzed as follows:

Composition of Outer Slag Layer*

SiO_2	60.67	MgO	4.87
		Na_2O	14.53
Al_2O_3 } Fe_2O_3 }	8.24	BaO	0.99
		SO_3	0.49
CaO	9.42		

* All analyses performed by E. W. Summers, Chief Chemist, Owens-Illinois Glass Co.

The second problem was the brick for the port side walls proper and the top checker courses. These brick were exposed to enormous quantities of batch dust and alkali vapors but at a temperature of 2300°F instead of 2750°F. They were also subjected to some spalling action during cleanout periods.

If too refractory a brick were used the batch dust would accumulate in a thick crust and clog the checker openings. A brick that was not refractory enough would slag away so rapidly

* Presented at the Annual Meeting, American Ceramic Society, Buffalo, N. Y., February, 1935 (Refractories Division). Received March 2, 1935.

that it would drip down into and clog the lower checker openings.

The proper brick for this use was one which would glaze over to prevent incrustation, thus keeping the openings clear, but would also slag away so slowly that the drippings would not appreciably clog up the lower openings before the maximum life was secured from the furnace. The composition of the loose deposit of batch dust clogging the checkers of furnaces melting a typical bottle glass and the composition also of the refractory drippings found in the lower checker courses were as follows:

Composition of Batch Dust Clogging Checkers

	Upper courses	Lower courses
SiO_2	22.50	12.51
R_2O_3	3.87	2.14
CaO	24.98	26.04
MgO	24.41	22.05
BaO	1.02	0.82
SO_3	14.89	27.19
Na_2O	8.33	9.25

Composition of Refractory Drippings

SiO_2	51.00	Na_2O	14.95
Al_2O_3	19.60	BaO	0.78
Fe_2O_3	2.19	TiO_2	1.27
CaO	4.85	SO_3	0.93
MgO	4.31	Ignition loss	0.12

III. Tests Conducted

The various tests conducted on the majority of brands were expansion, solubility, absorption, slag, bulk specific gravity, water-d.p spalling test, petrographic analyses, and a study of the size and shape of grog particles and of the bond and texture of the brick.

All of the tests, except the slag test, were made by the standard methods.

(1) Slag Test

Slag tests on those refractories for use in the locations described under the first part of the problem were conducted as follows:

An opening was made in the port-nozzle wall directly behind the burner block of the last port toward the charging end of an operating furnace. Six half brick were set with the skin edge toward the fire in a row across the top of the baffle wall. They were spaced two inches apart and the brick on each end of the row were spaced the same distance from the side walls by inserting a blank between them and the side walls. This insured equal velocity of gas flow between samples. They were left in this position for twenty-eight days of exposure. The volume loss was determined on each brick. The test was repeated on duplicate samples of the same brands, except that they were placed in different order across the width of the port. In many cases, three tests were made so that any variation in the gas velocity from the center of the port toward the side walls would be taken into consideration.

Due to the sampling tube becoming clogged, attempts to determine actual velocity differences were unsuccessful. This factor, however, did not appear to have any appreciable effect on the test. The factor of conductivity was intentionally neglected because a large percentage of these brick, when in actual service, are exposed to heat on all sides.

The test position just described will be designated as test position No. 1.

This same slag test was run on brick used in locations described under the second part of the problem, except that the test specimens were placed in a different location and the test was continued for forty-two days instead of twenty-eight days. These test pieces were placed on top of the dividing wall in the checker chamber and were located three feet above the top course of checkers and directly under the rear port opening. This position will be referred to as position No. 2.

Duplicate tests run in both No. 1 and No. 2 positions seldom showed a difference of percentage loss on the same brand of over 2.5%.

IV. Petrographic Work

Accurate petrographic data on high alumina brick, due to submicroscopic crystals, require X-ray patterns. Brick mixes were made up of grains of varied constitution and reactions between grains were only at points of contact. Nevertheless, by using Bowen and Greig's chart as an aid and by making careful petrographic analyses of both powdered slides and thin sections, a fairly accurate estimate of the crystalline content of the high alumina brick tested was obtained.

It was found that first-grade brick and 50% alumina brick are not greatly altered petrographically when fired only to about 2050°F. Above this temperature, however, mullite begins to form in increasing amounts; particularly around 2550°F, and at 2750°F it is quite complete.

TABLE I

BRICK DATA CHART

Brand No.	Method of manufacture	Al_2O_3 content	Linear expansion (%) to 900°C	P.C.E.	Wt. lost in water-dip spalling test: Loss (%)	Wt. lost in water-dip spalling test: No. of dips	Bulk specific gravity	Absorption (%): Brick	Absorption (%): Grog	Volume loss in slag test: No. 1 position	Volume loss in slag test: No. 2 position	Mineralogical content
1	D. P.	40	0.59	31	2	50	2.08	11.5	9.4		33	45% minute needles of mullite; 55% opaque amorphous material serving as a matrix for the mullite needles; about 5% of this material appeared to be cristobalite and glass
2	D. P.	40		30	25	50	2.12	10.5			40	30% minute needles of mullite; 70% opaque amorphous matrix
3	D. P.	41		32	30	25	2.16	10.2			37	43% minute needles of mullite; 57% opaque amorphous matrix with about 5% cristobalite and glassy material dispersed throughout
4	D. P.	40	.42	30			2.21	7.5	7.5		46	10% minute needles of mullite; 90% amorphous material with an occasional grain of quartz
5	D. P.	40	.53	31	10	50	2.21	7.5			30	38% minute needles of mullite; 62% amorphous matrix with about 2% cristobalite and glass scattered throughout
6	S. P.	40		31			2.10	9.2			36	45% minute needles of mullite; 55% amorphous material with approximately 5% cristobalite and glass throughout
7	De-aired	40		31	23	16	2.12	7.4			34	45% minute needles of mullite; 55% amorphous matrix with about 8% cristobalite and glass throughout
8	H. M.	40		30			2.02	8			80	36% minute needles of mullite; 64% amorphous matrix high in glassy material with occasional quartz grains
9	S. M.	40		30			2.17	4			47	40% minute needles of mullite; 60% amorphous matrix high in glassy material
10	S. M.	40		30			2.17	4			44	40% minute needles of mullite; 60% amorphous matrix high in glass
11	D. P.	42	.60	33	2	75	2.32	7.4	5.26		39	50% small well-formed mullite crystals; 50% amorphous matrix high in a siliceous glass
12	D. P.	42	.60	34	1	75	2.52	5.2			26	56% well-developed mullite crystals of 0.010 mm. length and 0.002 mm. width; 44% glassy matrix with some amorphous material
13	D. P.	45		34	16	50	2.30	6.50	5.30		43	55% small mullite crystals; 45% noncrystalline matrix high in glass and with occasional quartz grains present
14	D. P.	45		34			2.36	6.60	3.50		45	50% minute needles of mullite; 50% amorphous matrix high in glass
15	D. P.	45	.57	33	3	75	2.47	7.00			39	55% small mullite crystals; 45% opaque noncrystalline matrix high in glass and cristobalite with occasional quartz grain present
16	D. P.	52		34			2.13	9.70			38	65% small mullite crystals; 35% noncrystalline material high in cristobalite
17	D. P.	60		34			2.45	10.40		41		56% well-formed mullite crystals; 15% corundum plates; 20% glass and amorphous matrix
18	Slip cast	60		34			2.10	9.30		32		60% fine lathe-shaped mullite crystals; 10% corundum; 5% quartz; 25% amorphous matrix high in glass
19	D. P.	60		36			2.50	10.90		34		70% finely divided mullite crystals; 5% corundum; 25% noncrystalline matrix material with very little glass present
20	D. P.	60		34			2.42	11.5		46		50% corundum crystals; 30% mullite crystals; 20% amorphous material and glass
21	D. P.	60		34			2.43	9		34		60% fine mullite crystals; 20% corundum; 20% amorphous material and siliceous glass
22	D. P.	70		36			2.38	11.0		54		30% corundum crystals and plates; 30% mullite crystals; 40% amorphous matrix with some glass
23	D. P.	70		36			2.46	11.8		50		55% mullite crystals; 10% plates and corundum crystals; 35% amorphous material and glass
24	D. P.	73	.55	37			2.40	11.30	16.4	20		60% well-formed corundum plates; 15% well-developed mullite crystals; 25% amorphous material with some quartz present
25	D. P.	80		38			2.51	5.1		18		40% crystals and corundum plates; 40% well-developed mullite crystals; 20% glassy matrix with small amount of amorphous material
26	D. P.	80	.56	38	30	8	2.45	13		12		45% crystals and plates of corundum; 45% well-formed mullite crystals; 10% glass and amorphous material
27	D. P.	78	.56	38			2.73	7.5	5.2	18		50% crystals and plates of corundum; 45% large mullite crystals; 5% glass and amorphous material
28	D. P.	80		38			2.80	3		60		70% large corundum plates; 20% large mullite crystals; 10% glass; no amorphous material present

V. Scope of Test Work and Correlation with Service Conditions

The work described here was carried out during a period of two years, in which time more than 100 different brands of brick were tested and a complete record was kept of the properties and performance of each brick. The brick tested ranged from a first-grade fire brick to super-refractories of the 80% alumina class, and the price level varied from $45.00 to $775 per thousand.

Those brick which had given the best results in all of the tests were chosen and used in the construction of several furnaces. The performance of these refractories was observed

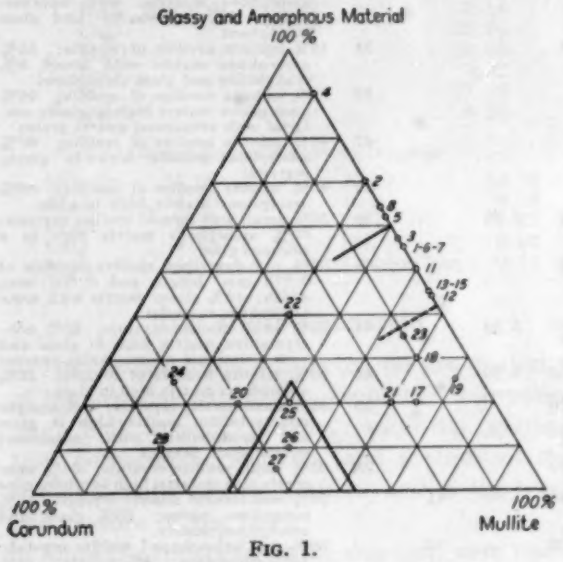


FIG. 1.

during an entire furnace campaign, and the results secured in actual practice were found to be in remarkable agreement with those secured in the test work. The final results in both the test work and actual practice were then correlated. The properties of both the satisfactory and unsatisfactory refractories were studied carefully and an attempt was made to determine upon what particular properties the superiority of the most satisfactory refractories depended. Test brick were then made up and further tests were conducted. An examination of the results of these last tests indicated quite clearly what definite properties were wanted in the brick as received.

A method was then formulated by which these controlling factors could be measured accurately enough to enable a reliable choice of refractory for service conditions to be made. This control method consumed only a short time and eliminated the initial exhaustive service tests.

VI. General Data Secured

Although more than one hundred brands of refractories were tested, it is thought necessary to present only the data and discussion on twenty-four brands which were representative of each main type of brick tested. Table I presents briefly the data secured on these brick.

VII. Discussion of Data

Data on specific gravity determinations, absorption, spalling, pyrometric cone equivalent, and chemical composition will not be discussed in detail.

In general, when a clay is heated it is slowly converted into mullite, cristobalite, and glass. When diaspore is subjected to heat treatment it tends to form alpha corundum with an increase in specific gravity and a decrease in volume. Sillimanite, kyanite, and andalusite invert to mullite under heat treatment with a decrease in specific gravity and an increase in volume. Preliminary work indicated that the extent of such conversions already present in a brick as received were of the utmost importance as far as resistance to slag attack was concerned. The conclusions drawn with reference to crystalline development, however, are not meant to infer that the amount of the crystalline phase present in a brick is the sole answer because it emphatically is not.

(1) Brick Tests in No. 1 Position

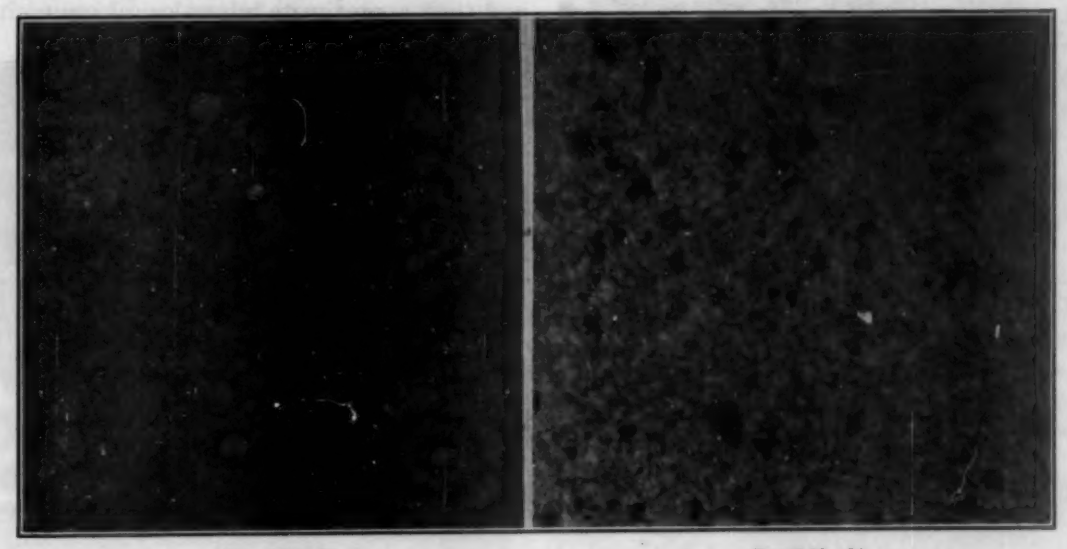
For purposes of comparison, the three main mineralogical constituents of these brick have been set down as the corners of a triaxial diagram (Fig. 1). For the more exact mineralogical composition, the description in Table I should be referred to.

Approximate mineralogical compositions of the twelve brands of brick selected are represented on Fig. 1. These twelve brands with absorption values and slag losses are given in Table II.

Brands Nos. 26, 25, and 27 were far superior to the other nine brands and of these three brands, No. 26, which had the highest absorption, was the best. All of these twelve brick were directly

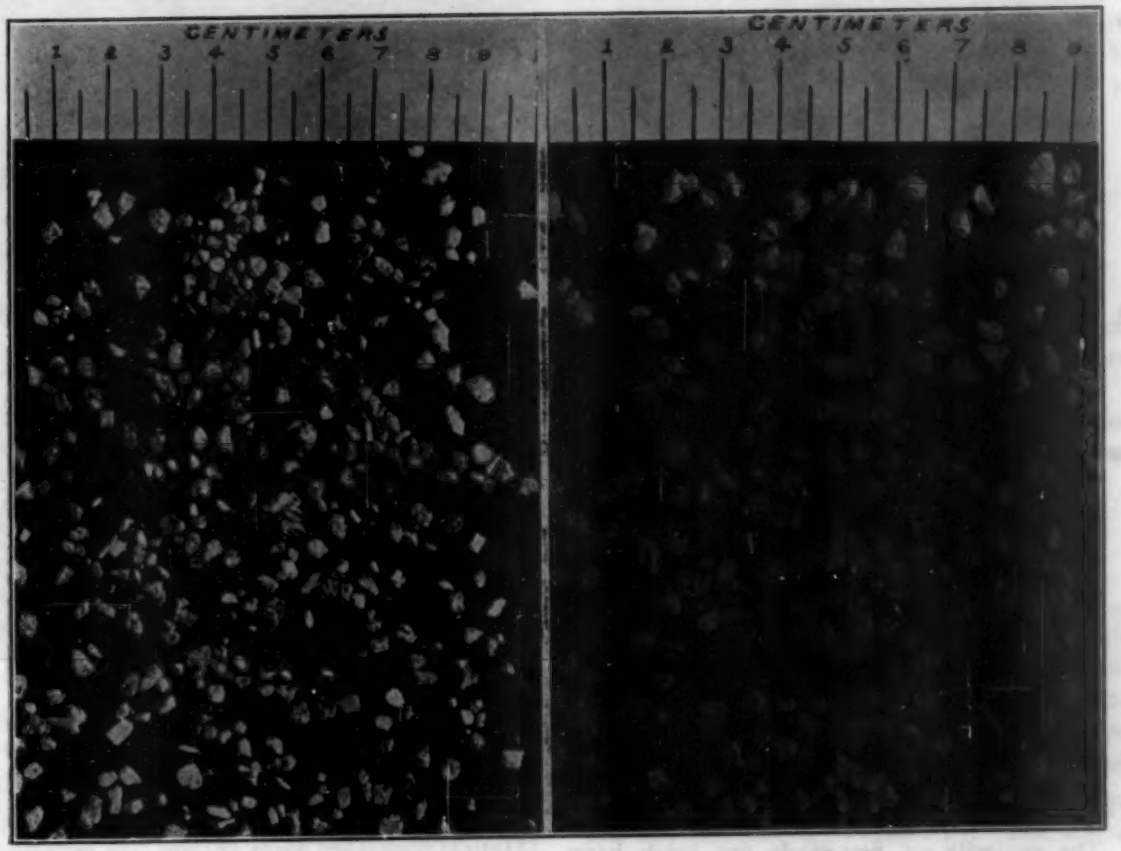
slagged away except brand No. 28, which appeared to crumble off in small pieces rather than to slag.

On Fig. 1, these three outstanding brands are within the following mineralogical limits: 5 to 20% glass and amorphous material, 40 to 45% crystalline mullite, and 40 to 50% crystalline corundum.



Brand No. 27 Brand No. 24

FIG. 2.



Brand No. 24 Brand No. 27

FIG. 3.

All physical factors undoubtedly played a large part in the performance of these brick, but the ones appearing to have the most influence were the properties of the grog and texture of the brick. The textures of brands Nos. 26, 25, and 27 were all homogeneous and free from hairline cracks around grog particles. The pore spaces were small and non-interconnecting and the grog itself was of uniform size and shape and did not vary from fine to coarse. Figure 2 shows the difference in texture of brand No. 27 and of a brand such as No. 24, having greater loss. Figure 3 illustrates the type of grog used in each of these brick. Table III gives the absorption of brands Nos. 24 and 27.

TABLE II

Brand No.	Absorption (%)	Volume lost in slag test (%)
26	13.0	12
25	5.1	18
27	7.5	18
24	11.3	29
18	9.3	32
19	10.9	34
17	10.5	41
20	11.5	46
28	3.0	60
22	11.0	54
21	9.0	34
23	11.8	50

TABLE III

Brand No.	Absorption of brick (%)	Absorption of grog (%)	Volume loss in slag test (%)
24	11.3	16.4	29
27	7.5	5.2	18

Grog particles in brand No. 24 were soft and friable with a higher absorption than the brick as a whole.

Three brick were made and fired to the necessary temperatures to secure crystalline development in each one listed as follows:

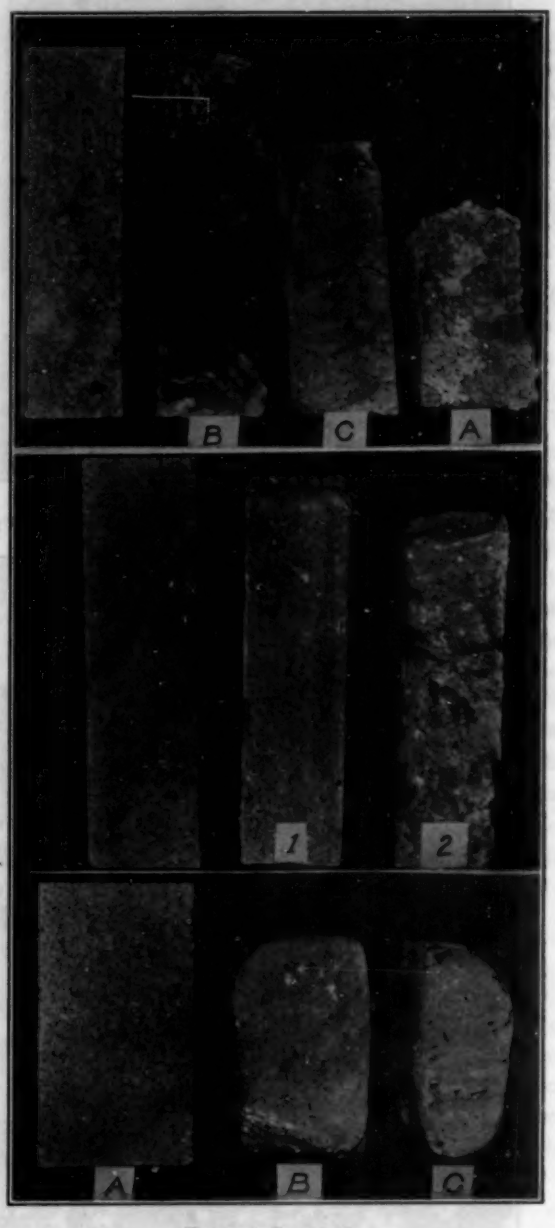
(A) 80% Al_2O_3, very little crystalline development.
(B) 80% Al_2O_3, maximum crystalline development.
(C) 60% Al_2O_3, maximum crystalline development.

These three brick were placed in No. 1 test position side by side for twenty-eight days. Figure 4 shows these brick after their removal; originally all were the same size as the 9-inch straight at the left. This indicates that not only the amount of alumina present but also the form in which it is present is of utmost importance.

(2) Brick Tested in No. 2 Position

The majority of first-grade fire brick have practically the same composition and general properties. Out of the large number of brands tested, however, there were several found that were outstanding in performance.

Twelve brands were selected from these brick and their approximate mineralogical composition



FIGS. 4, 5, AND 6.

FIG. 4 (top).—Showing brick after 28 days in No. 1 test; all originally were the same as the 9-inch straight at the left.

FIG. 5 (center).—Showing brands Nos. 1 and 2 after test of 42 days.

FIG. 6 (bottom).—Showing comparative test results: (A) size of original test pieces; (B) fired 2740°F, maximum mullite development; (C) fired to 2352°F, little mullite development.

was designated on one side of the triaxial in Fig. 1. These twelve brands with absorption and volume losses in the slag tests are given in Table IV.

TABLE IV

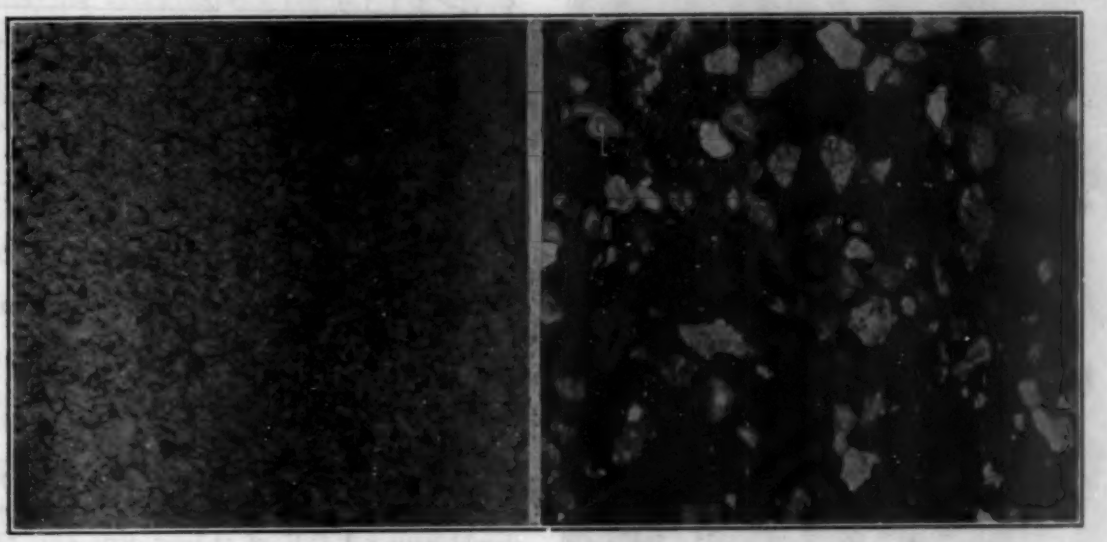
Brand No.	Absorption (%)	Volume loss in slag test (%)
1	11.5	33
2	10.5	40
3	10.2	37
4	7.5	46
5	7.5	39
6	9.5	36
7	7.4	35
8	8.0	80
11	7.4	39
12	5.2	26
13	6.5	43
15	7.0	39

The most outstanding brick in this group were brands Nos. 1, 3, 6, 7, and 12. The crystalline content fell between the following limits: 57 to 44 glass and amorphous material and 43 to 56% crystalline mullite.

For this type of brick, the more crystalline mullite present, the better it resisted slag attack, providing the other physical properties were also correct as is evident from the fact that although brands Nos. 11, 13, and 15 are in the same limits of constitution variation as the five brands which show low loss, their losses of volume due to slag erosion were high. In Fig. 1, the solid line intercepting these brick compositions indicates the lower limit allowed for mullite development and the dotted line shows the maximum percentage of mullite found in the brick which were investigated in this work.

Figure 5 shows results secured on brands Nos. 1 and 2. These two brick were tested side by side for forty-two days. They were almost exactly similar in chemical composition, absorption, conductivity, specific gravity, grain size, texture, and other physical properties. The chief measurable difference between these two brands was the amount of crystalline mullite development in the brick as received. The direct beneficial result of high mullite development was tested as follows:

Two brick were made up from a chosen brick mix of clays. One of these brick was fired to 2352°F and the other one to 2740°F. One half of each of these brick, which were identical except for the firing, was placed side by side in No. 2 position and left there for 42 days. Figure 6 illustrates the results secured.



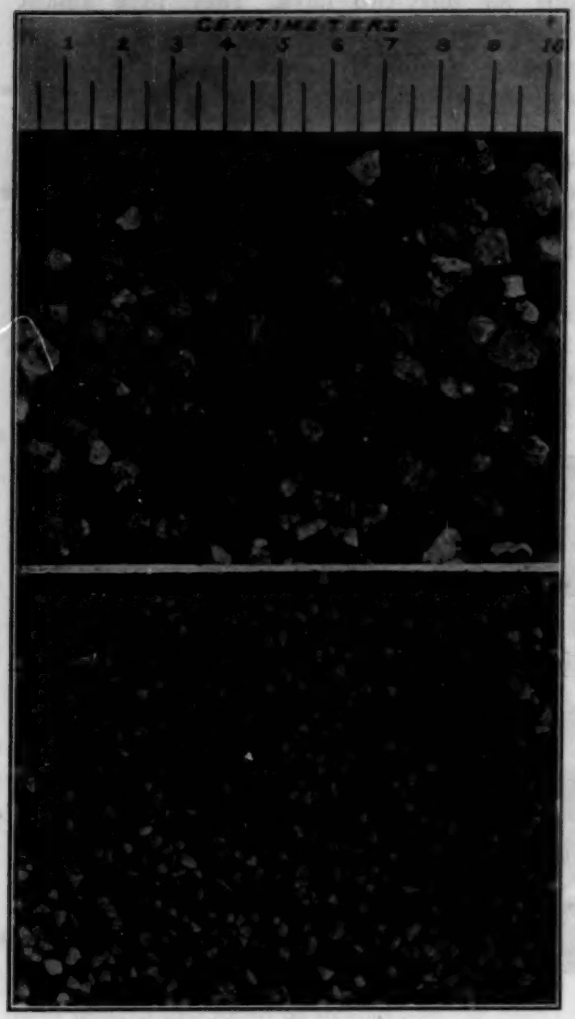
Brand No. 1 Brand No. 4

FIG. 7.—Texture of brick.

(A) Size of original test pieces.
(B) Brick fired to 2740°F with maximum mullite development.
(C) Brick fired to 2352°F with very little mullite development.

The texture, shape, and size of grog particles undoubtedly had some effect on all of the above brands, but the exact extent of their importance was not determined satisfactorily. The texture of brick and type of grog used in brands Nos. 1

and 4 are shown in Figs. 7 and 8. A brick consisting of large coarse grog particles surrounded by hairline cracks disintegrated much more rapidly than one with smaller, more uniform, and well-bonded grog particles.



Top, Brand No. 4 Bottom, Brand No. 1
FIG. 8.—Type of grog.

(A) Expansion Data

Although the complete expansion curves from room temperature up to 900°C were determined on the majority of brands tested, they were not of great value. Observations indicated that a high rate of expansion under 200°C was due mainly to the presence of cristobalite. Expansion curves are indicative of the mineralogical content in a great many cases, but in others the degree of firing must be first known in order to interpret the curve correctly.

Heindl and Pendergast[1] showed that approximately the same curve could be obtained on some clays fired to 1120°C and 1525°C, with entirely different mineralogical content. As the present work dealt with brick as received and the degree of firing was often unknown, it was decided to omit using expansion data as a guide. As a matter of interest, Fig. 9 gives the expansion

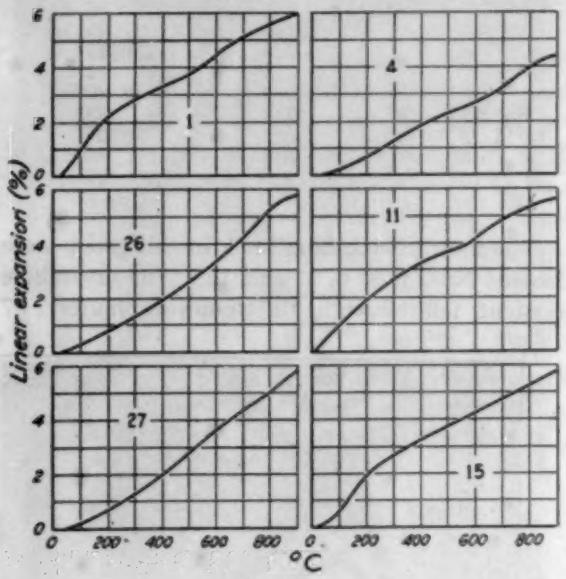


FIG. 9.

curves on six brands, which are representative of each general type of brick tested.

VIII. Conclusions

The conclusions reached regarding brick for service in the locations included under the first part of the problem were as follows: The brick should have a P.C.E. of at least cone 34. They should be of even texture and preferably of fine grain size. Grog in the brick should be of uniform size and shape and its absorption should not be greater than that of the brick as a whole. The absorption of the brick as a whole is relatively unimportant as long as the pore spaces are evenly divided and non-interconnecting.

Large fissures should not be present in the texture of the brick as they are easily penetrated by the furnace gases and vapors. With small pore spaces, the viscous glaze formed over the surface protects the interior of the brick from

[1] R. A. Heindl and W. L. Pendergast, "Fire Clays, Some Fundamental Properties at Several Temperatures," *Jour. Amer. Ceram. Soc.*, **13** [10] 741 (1930).

penetrating vapors and reducing gases. The mineralogical content should fall somewhere within the area designated on the triaxial. The mineralogical structure should consist as nearly as possible of large, well-formed interlocking crystals with the matrix full of minute crystals and a minimum of glass and amorphous material.

The properties desired in the brick for use in the locations described under the second part of the problem are somewhat different. The property of absorption was quite important while that of P.C.E. was secondary. The absorption should be between 5% and 12%, and the P.C.E., cone 31. These brick should also have the necessary spalling resistance that is demanded by service conditions, as well as proper heat capacity and heat-exchange value. The texture should be particularly free from hairline cracks around grog particles as soda-ash and lime dust have a special affinity for attacking such cracks. The mineralogical content should fall within the area designated on Fig. 1, bearing in mind that a still higher mullite content than that specified would probably be even more satisfactory.

Acknowledgment

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BIBLIOGRAPHY

(1) H. E. Simpson, "A Classified Review of Refractory Slag Tests," *Jour. Amer. Ceram. Soc.*, **15** [10] 520 (1932).

(2) H. E. Simpson, "An Investigation of the Action of Coal-Ash Slags on Fire Brick by Microscopic Methods," *ibid.*, **15** [10] 536 (1932).

(3) C. E. Grigsby, "Effect of Typical Slags on Fire Brick with a Method of Determination Correlated to Service," *ibid.*, **12** [4] 241 (1929).

(4) K. G. Skinner and N. L. Field, "Action of Waste Wood Ash on Refractories," *ibid.*, **16** [8] 393 (1933).

(5) L. R. Faulkner, "The Slagging Action of Fuel-Oil Ash," *Bull. Amer. Ceram. Soc.*, **13** [2] 45 (1934).

(6) B. C. Ruprecht, R. H. H. Pierce, and F. A. Harvey, "Study of the Effect of Natural Gas and Hydrogen upon Various Refractories," *Jour. Amer. Ceram. Soc.*, **17** [7] 185 (1934).

(7) J. F. Hyslop, A. Gumm, and H. Biggs, "Some Corrosion and Erosion Phenomena and Their Bearing on the Macrostructure of Refractories," *Jour. Soc. Glass Tech. (Trans.)*, **10**, 405 (1926).

(8) W. J. Rees, "Alumina-Silica Minerals in Fire Brick," *Trans. Ceram. Soc.* [Eng.], **24**, 25 (1924–25).

(9) J. F. Hyslop, "The Chemistry of a Fire Brick," *Jour. West. Scot. Iron & Steel Inst.*, **40**, 23–28 (1932–33).

(10) O. Lecher, "Investigation of the Resistance of Refractories to the Attack of Slags and Glasses," *Sprechsaal*, **62**, 390 (1929).

(11) T. N. McVay, "Optical Methods as an Aid to the Study of Refractories," *Jour. Amer. Ceram. Soc.*, **12** [7] 455 (1929).

(12) F. Hartmann, "Quantitative Estimation of the Attack of Slag and Flue Dust on Refractories," *Stahl & Eisen*, **47**, 182 (1927).

(13) J. F. Hyslop and H. C. Biggs, "Slag and Spalling Tests on Fire Brick," *Trans. Ceram. Soc.* [Eng.], **30**, 288 (1931).

(14) Proposed Tests of Resistance of Refractories to Slag Attack (Specification D. I. N., E-1069), *Tonind.-Ztg.*, **54**, 846 (1930).

(15) W. Miehr, J. Kratzert, and P. Koch, "A Contribution to the Question of the Resistance of Refractory Materials to Corrosion," *ibid.*, **54**, 810, 907, 908 (1930).

(16) A. Clausset, "Durability of Refractories," *Rev. belge ind. verrières*, **1**, 120, 148 (1930).

(17) T. Nakai and Y. Fukami, "X-Ray Examination of Some Ceramic Raw Materials," *Jour. Soc. Chem. Ind.* [Japan], **36**, 559–62 (1933).

(18) D. S. Beliankin and M. A. Besborodov, "Action of Dust from the Batch on the Checker Brick of Glass Furnace Regenerators," *Jour. Amer. Ceram. Soc.*, **13** [5] 346 (1930).

(19) J. H. Partridge and H. C. Biggs, "Glass House Refractories, a Study of Corrosion Resisting Properties," *Jour. Soc. Glass Tech. (Trans.)*, **14**, 63 (1930).

(20) S. J. McDowell and H. C. Lee, "A Petrographic Study of Some Slags from Boiler Furnaces," *Jour. Amer. Ceram. Soc.*, **11** [1] 35 (1928).

(21) T. N. McVay and C. L. Thompson, "X-Ray Investigation of the Effect of Heat on China Clays," *ibid.*, **11** [11] 829 (1928).

(22) T. N. McVay and R. K. Hursh, "Some Effects of Coal Ash on Refractories," *ibid.*, **11** [11] 869 (1928).

(23) R. F. Ferguson, "Review of Literature on Laboratory Slag Tests of Refractories," *ibid.*, **11** [2] 90 (1928).

(24) W. F. Rochow, "Super-Refractories for the Iron and Steel Industry," *Iron & Steel Ind.*, **11** [8] 296 (Aug., 1934).

(25) F. S. Thompson and H. M. Kraner, "Refractories for the Manufacture of Glass," *Ind. Eng. Chem.*, **25**, 848–72 (1934).

THE TIME FACTOR IN THE TESTING OF GLASSWARE*

By F. W. Preston

Abstract

A preliminary report on the effect of the time element on the apparent strength of glass is given. Tests have been run on bottle glass from three seconds to 30 minutes duration and on polished plate and drawn window glass (in the form of laths) from five seconds to several hours.

I. Introduction

When a piece of glass is twisted or stretched or distorted for any but the briefest time, it gets "cramps" in its distorted position. This was shown recently by Spencer, who wrapped the fibers of glass round a small glass cylinder, held them there for months, and then found they had a "permanent set." They did not become straight again on being cut loose from the cylinder. But the "set" was not so permanent after all; if left floating on mercury, they gradually straightened.[1] Thus it was not a plastic or viscous flow but an elastic phenomenon.

II. Elastic After-Working

This "elastic after-working" has been known for some time. Much work was done on it in Germany a generation or more ago in connection with the change of zero point in thermometers, where a "thermal after-working" is encountered.[2] The strictly elastic (as distinct from thermal) effect was investigated also by Phillips some thirty years ago.[3] Phillips does not give the composition of his glass or any references to the literature. He experimented with fibers of glass in direct tension, and measured the stretch (x) under various loads and after various lengths of time, as given in the following example.

Stress (779 kg./cm.²) Stretch (x) in arbitrary scale divisions	In Corning's units (7.79 kg./mm.²) Log (time)	In English units (11,000 lb./sq. in.) $(x - a)/\log t$
289.7	0.38	2.63
290.2	.50	3.0
290.6	.66	2.88
291.0	.86	2.68
291.3	.94	2.77
291.75	1.15	2.66
292.3	1.32	2.73
292.5	1.40	2.72
292.9	1.54	2.73
293.2	1.65	2.73
293.8	1.90	2.69
296.7	2.92	2.74

The last column is given to show the agreement of the experimental results with the empirical formula.

Stretch $(x) = a + b \log t$.

Where a and b = constants for the particular experiment.

For above load of 11,000 lb./sq. in. or 7.79 kg./mm.², $b = 1.55 \times 10^{-6}$

For load of 5.99 kg./mm.², $b = 1.16 \times 10^{-6}$

For load of 4.22 kg./mm.², $b = 0.78 \times 10^{-6}$

By plotting these values of b against the loads producing them, Phillips concludes that b would become zero at a load of 2.84 kg./mm.² or 4000 lb./sq. in. In other words, for stresses as low as this there would be no "creep" or gradual stretching. This point does not appear to have been investigated experimentally.

III. Nature of Creep

The nature of the observed creep is an interesting matter for speculation. When a sudden tension is applied to a glass fiber, the process is adiabatic. The temperature of the specimen falls slightly, so that a slight thermal contraction takes place and opposes the stretch due to the load. As the temperature equalizes, the fiber extends a slight additional amount, giving the isothermal stretch.

This, however, does not explain the observations, since temperature equilibrium is attained quickly, and the slow stretch persists for a long period.

For the same reason, any supposition (in its ordinary form) that the stretch produces an electric polarization or piezo-electric effect, which tends to oppose the stretch, must be rejected. Spencer[1] floated fibers on mercury, which would give surface electricity an excellent chance to attain prompt equilibrium.

For the present it seems convenient to regard it as a slow mechanical polarization of the glass; certain atoms or ions in the structure are forced into different positions or are rotated slightly into attitudes more convenient in the strained state. On releasing the stress, they slowly return to the

* Presented at the Annual Meeting, American Ceramic Society, Buffalo, N. Y., February, 1935 (Glass Division).

[1] C. D. Spencer, "Discussion of Flow of Glass Subjected to Strain." Presented at the Annual Meeting, American Ceramic Society, Cleveland, Ohio, February, 1931; not published.

[2] H. Hovestadt, Jena Glass, p. 304. English ed., 1902.

[3] Percy Phillips, *Phil. Mag.*, **225** [Ser. 6, Vol. 9] 520–22 (1905).

attitudes or positions convenient in the unstrained state. This mechanical polarizing and depolarizing is probably effected with the help of the thermal vibrations of the ions, which is present at all temperatures above absolute zero, and thus the rate of creep observed will probably be found to vary considerably with any large variation of temperature. It seems likely also that it could be accelerated in an alternating electric field.

Be that as it may, it is known that all glasses are not alike in exhibiting creep.

IV. Deformation Preceding Rupture

A little earlier than Phillips' experiments in England, Grenet's experiments were made in France.[4]

NOTE: Inasmuch as the English version in a recent issue of *Glass Industry* was curiously curtailed, the significant parts of the missing paper are given here.

"The writer has tried to determine whether the delay in fracturing in the cross-bending tests was accompanied by a permanent deformation or 'set,' increasing slowly from the time the load was applied up to the moment of rupture.

"For this purpose, a plate of No. 4 glass, 25 by 3 millimeters in section (1 by 1/8 inch) with smoothed edges, was loaded in the same manner as in the breaking tests, applying the load at a rate of 1 kilogram in 2 minutes until a stress of 4 kg./mm.^{2} was developed.

"A 'test plate' of glass was placed on the specimen whose strength was under investigation, and the combination was illuminated with the yellow sodium flame.[5]

"With the aid of a magnifying glass, one of the interference fringes thus produced was watched attentively.

"While the specimen was being loaded, the deflection of the glass produced a displacement of the fringes, and as soon as the flow of water into the bucket was stopped and the load became constant, the fringes ceased to move.

"When a load of 6 kg. was reached, corresponding to a stress of 4 kg./mm.^{2}, no further load was added; thereupon the fringes ceased to move and at the end of 2 or 3 minutes fracture took place.

"While the last kilogram was being added, 70 fringes were observed to pass (black band to black band, extinction to extinction); no displacement of the fringes was observed from the moment when the writer ceased to add weight until the moment of fracture.

"As a movement of 1/4 of a fringe would certainly have been detected, it is seen that if there had been a permanent deformation (or creep) it must have been of the order of magnitude which corresponds to a very small increment of elastic deformation; in fact, the permanent set must have been less than the deflection caused by adding 3 1/2 grams weight.[6]

"The increase of stress or strength which would result from this increased load under a more rapid rate of loading would be insignificant, *viz.*,

$$R = 4.002 \text{ kg./mm.}^2, \text{ in place of } 4.000,$$

and does not suffice to explain the differences of strength found with different rates of loading.

"In another similar test, the glass plate was loaded up to 3.8 kg./mm.^{2}, and 80 fringes were observed to pass during the loading of the last kilogram; no sensible displacement of the fringes from the time the loading stopped up to the time the glass broke, several minutes later, could be detected.

"This delay in fracturing is known to the champagne makers, who never refill their bottles a second time, in spite of their relatively high price; it is likely that the explosions of bottles of Seltzer water, taking place long after the bottles are placed in service, may be connected with this phenomenon.*"

Thus, while Phillips found creep, Grenet did not. Incidentally, Grenet gives as the composition of the glasses:

St. Gobain's No. 4 glass (%)		St. Gobain's "Cathedral" glass (%)	
SiO_2	71.75	SiO_2	70.98
$Al_2O_3 + Fe_2O_3$	1.50	$Al_2O_3 + Fe_2O_3$	1.56
CaO	14	CaO	14.94
Alkali and SO_3	12.75	Alkali and SO_3	12.52

Grenet's tests were made in cross-bending ("transverse tests"), and the load was carried to the breaking point, while Phillips' were not.

Spencer's glass, which showed creep or mechanical polarization, was presumably a lamp glass.

[4] *Bull. soc. encour. ind. nat.* [Ser. 5] **4**, 838 (1899); partial English version in *Glass Ind.*, **15** [11] 277–80 (1934).

[5] *Translator's note:* This "interference" test is unfamiliar to most glass manufacturers, but is well understood in physical laboratories, and is shop practice in optical glassworking plants.

[6] *Translator's note:* In the French version, this figure is derived by a formula, but as usual, the formula has a misprint, though the result is right.

* End of Grenet translation.

The composition was SiO_2 63%, K_2O 6%, Na_2O 9%, and PbO 22%.

Littleton,[7] experimenting at about the same time as Spencer, on strong rods of borosilicate, found no creep. Very high stresses and delicate optical tests were used with negative results.

G. A. McKee, experimenting for the present writer on the cross-bending of plate-glass laths, found virtually no measurable creep in tests lasting 4 to 15 hours. (See page 223 following.)

Borchard, in contemporaneous tests in Germany, seems to have found considerable creep.[8]

Fused silica is the most elastic (*i.e.*, creep-free) material available for delicate scientific work. Thus it is used in the suspension fibers of galvanometers. High silica glass comes next and is used for thermometers. Plate glass is also quite good and is used in all the big telescope mirrors in effective use to date, though apparently destined to be superseded by the low-expansion borosilicates which are equally free from creep. Some of the softer glasses are apparently not free from creep, and it is supposed that the mechanical polarization consists in squeezing the sodium ions, or similar loosely held atoms, out of their normal attitudes in the (more or less) octahedral spaces of the glass "lattice."

But most experimenters seem agreed that the total amount of creep observed is very small in comparison with the elastic part of the stretch. Thus, Phillips found an elastic stretch of 290 scale divisions and a creep of 7 divisions after a long period. Spencer wrapped the fibers (of about 0.1 mm. diameter) round a rod or tube 2 centimeters in diameter and held them there for about 1000 hours. On cutting them loose, they immediately opened up to coils some 60 centimeters in diameter, and this radius of curvature continued to increase with time, *i.e.*, the fiber continued to straighten. In the case of a few fibers still in existence after being cut loose five years ago, there is still evidence of curvature.[9]

V. Breaking Load under Continued Stress

Turning to the breaking load under continued stress, a totally different state of affairs is found. Glass will not stand a long-continued load of anything like the proportions it can stand for a few moments. It is not a difference of 1/2 of 1%, as in Phillips' stretch, but a reduction of strength of 25 or 50% in a comparatively short time.

This fact too has been known for many years, but the available data are most unsatisfactory. Grenet gives information, but the variability of his specimens in size and manufacture do not permit very definite conclusions. The measurement of breaking strength is a vastly more difficult thing than the measure of stretch, however small the latter may be. The trouble arises largely from the fact that what is being measured is not really known. The mechanical strength is always a small fraction of what it ought to be; it is extremely variable from specimen to specimen, even when the specimens are prepared at one time from one particular batch and under the most controlled conditions possible; it varies also with the state of the surface of the specimen and enormously with the size of the specimen. As ordinarily tested, it varies greatly too with the rate of loading. On the other hand, it seems to have a nearly zero temperature coefficient, *i.e.*, for practical purposes, strength is independent of temperature to a greater extent than with most other materials.

The writer's staff has been engaged for a year or two past in experimenting on these subjects, more particularly in the decrease of strength with continual loading. The experiments are far from complete, and it seems desirable here to give only a few outlines.

The following strength values were obtained on a plate glass of high quality, polished on the faces, diamond-cut on the edges, the diamond mark being in the compression face in a transverse test of the specimen, which was roughly 1/4 inch thick, 2 inches wide, 16 inches between supports, loaded centrally, and of the following chemical composition:

	(%)
Silicon dioxide	71.32
Sodium oxide	13.00
Calcium oxide	13.34
Magnesium oxide	0.23
Sodium sulfate	0.95
Sodium chloride	0.73
Arsenic pentoxide	0.17
Iron and aluminum oxides	0.20
	99.94

Duration of test	Average breaking strength of 20 specimens (lb./in.^{2})	
5 sec.	11,900	These specimens from a single sheet of polished plate
1 min.	8,600	
30 min.	6,000	
4 hr.	5,420	This from another plate

[7] J. T. Littleton, private communication.

[8] K. H. Borchard, "Elastic After-Effect in Glass"; *Sprechsaal*, **67** [20] 297 (1934); *Ceram. Abs.*, **13** [11] 290 (1934).

[9] Private communication, January 7, 1935.

Tests of a fine-grade Fourcault drawn window glass showed a rather similar course.

5 sec.	13,150 (av. of 25 specimens)	Glass 2 by 0.0125 in. on 4-in. centers, centrally loaded
1 min.	9,700 " " " "	
30 min.	7,950 " " " "	

The composition of this glass is more complex and will not be given until more extensive mechanical tests have been made. The surfaces are fire-polished and the edges diamond-cut with diamond mark on compression face.

The rate of decline of strength is similar for the two glasses above.

On the other hand, when tests were made of the endurance strength of bottles, the strength did not decline so fast with time. It fell off markedly, and the fact that it did not fall faster is something of a mystery. The bottle glass is higher in soda and lower in lime than the lath specimens, and it may be necessary to prepare laths of the bottle glass to see if the cause of the discrepancy is in the composition or in the method of testing.

The bottle tests were made on the precision testing machine designed by the author.[10] This machine imitates the conditions of service perhaps better than any other device, and the fact that the strength does fall off appreciably with time under these conditions warrants the attention of glass manufacturers to the inadequacy of "instantaneous tests."

The satisfactory determination of strength on the longer tests is a slow process, and the writer hopes soon to have a larger number of testing machines available so that a more complete investigation can be made.

The tests of long duration are particularly important, because it is far from clear whether the strength declines to some finite limit or whether it actually goes to zero on a very long test. What percentage of the strength (as ordinarily measured) is left at the end of a couple of years of testing should be determined.

Several experimenters have suggested that the strength declines to about one-half; Littleton, in conversation, has suggested one-third; the present writer is inclined to think the ultimate value may be zero. Borchard,[11] in the case of bottles, believes that if the specimen survives a 2-hour test it will last indefinitely.

VI. Real Instantaneous Strength

A point of less practical importance, but of considerable scientific interest, is, what is the real instantaneous strength? No actual test is instantaneous, for the inertia and elastic properties of the materials prevent that. Under impact tests, which is the nearest approach to instantaneity, a sharp increase of maximum stress is noticed as compared with tests lasting a few seconds.[12] The writer is, however, fairly well convinced that the true instantaneous strength is infinite, or that at least it equals the theoretical strength of the glass (perhaps a hundred times any of the ordinarily observed strengths). This conclusion is reached partly from the shape of the curve as shorter and shorter durations are used and partly from theoretical requirements. An ordinary crack must be propagated with a finite velocity, so that under an instantaneous test (lasting an infinitesimal time) no crack, such as we know it, could be propagated at all.

When the duration of the test becomes so short that there is no time for a crack to be propagated from one molecule to the next (about 10^{-8} of an inch), it is necessary for every thread or chain of molecules to break simultaneously if the specimen is to rupture as a whole. Not only that, but for the specimen to break as a whole, the points of rupture of the individual chains must be adjacent. This can only be attained in practice if every link of every chain breaks, a process which requires as much energy as one-third of the heat of vaporization and carries us to the theoretical strength of the glass.

With still shorter tests, it is doubtful if any meaning can be attached to the concept of strength.

The "set" acquired by the plate-glass laths on the 4-hour and 15-hour test was measured in each instance, except when the specimen broke. In all cases, it was very small and appeared to be about 1% of the elastic deformation. It was not sensibly different at 15 hours from its 4-hour value, and was measured immediately after taking off the load. Some "set," from $\frac{1}{2}$ to $1\frac{1}{2}$%,

[10] F. W. Preston, "Pressure Testing Machines," *Glass Ind.*, **15** [11] 252 (1934).

[11] K. H. Borchard, "Testing Bottles," *Sprechsaal*, **67** [38] 576–77 (1934).

[12] F. W. Peston, "Impact Strength of Glass," *Jour. Amer. Ceram. Soc.*, **14** [6] 432–34 (1931).

was always observed on loads near the breaking point, but the accuracy of the observations is not much greater than the apparent "sets." After careful examination, Mr. McKee came to the conclusion that the whole of the apparent set, amounting to a couple of ten-thousandths of an inch, was in the steel work of the apparatus and that no part of it that could be measured at all was in the glass.

BUTLER, PENNSYLVANIA

NOTE ON THE RELATION BETWEEN COBALT AND NICKEL-OXIDE CONTENT AND REBOILING OF SHEET-STEEL GROUND COATS*

BY J. M. CAYFORD AND R. M. KING

ABSTRACT

To a selected enamel varying amounts of cobalt and nickel oxides were added and the duration and persistence of reboiling were determined. These oxides were found to have a definite influence on reboiling.

It has been reported[1] that enamels which do not contain cobalt or nickel oxide, or both, will not reboil when fired on sheet steel and also that enamels containing these oxides will not reboil when fired on copper, silver, platinum, or gold. This report presents a special study to determine the relation between the amount and nature of these oxides and the duration and persistence of reboiling.

Duration was determined by placing the fired test piece in an electric furnace held at 1580°F and measuring the time between the beginning and end of reboiling with a stop watch. The persistence was obtained by repeating the reboiling test until there was no further appearance of bubbles on the surface. The number of times necessary to eliminate reboiling was taken as an index of persistence.

The composition of the enamel used was borax 30, feldspar 30, quartz 20, soda ash 8, soda nitrate 4, fluorspar 6, and special oxides 2% (approx).

Figure 1 shows results of these tests and from them, the following conclusions are made:

(1) With cobalt oxide alone, both persistence and duration of reboiling increased to a maximum at 0.4 to 0.5% and then decreased to practically zero at 2.0%.

(2) With nickel oxide alone both persistence and duration increased to a maximum at 1.5%. At 2%, duration was lower than the maximum, while the persistence remained about the same.

(3) When both oxides were present or when manganese oxide was used with cobalt and nickel oxides, there was a tendency toward a lower persistence and a shorter duration. In some cases, it seemed that the presence of manganese practically eliminated reboiling.

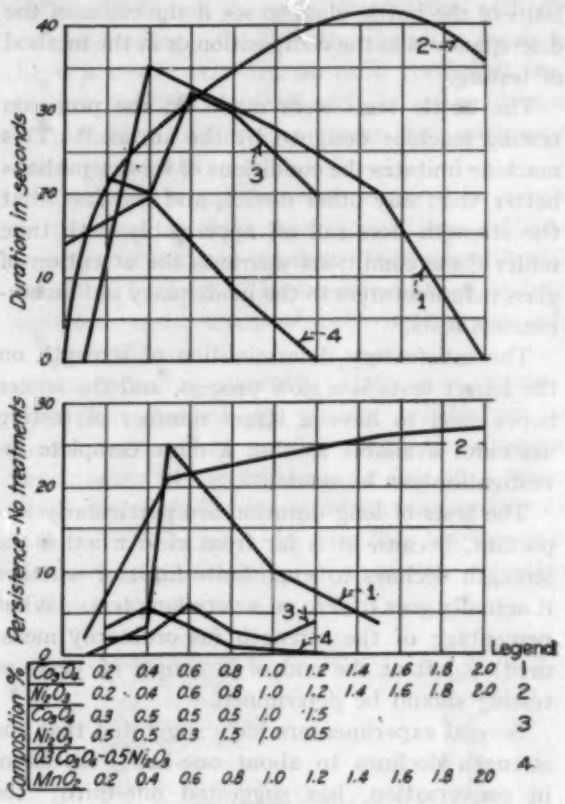

FIG. 1.

* Presented at the Annual Meeting, American Ceramic Society, Buffalo, N. Y., February, 1935 (Enamel Division).

[1] J. O. Lord, "A Summary of the Observations and Facts Concerning the Phenomenon of Reboiling," *Jour. Amer. Ceram. Soc.*, **16** [9] 442 (1933).

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OHIO STATE UNIVERSITY
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Abrasives

Boron carbide. R. R. Ridgway. *Trans. Electrochem. Soc.* [preprint], **66**, 16 pp. (1934); for abstract see *Ceram. Abs.*, **14** [2] 46 (1935).

PATENTS

Abrasive articles. C. E. Wooddell, C. S. Nelson, and Roy Lincoln (Carborundum Co.). U. S. 2,001,911, May 21, 1935 (April 21, 1932). An abrasive article comprises a flexible backing and a plurality of blocks of bonded abrasive material attached to the backing by a layer of resilient material of sufficient thickness to permit substantial yielding of the blocks under the pressures applied in grinding.

Abrasives. Carborundum Co. Fr. 771,793, Oct. 16, 1934; *Chem. Abs.*, **29**, 1600 (1935). Abrasive particles are coated with a fusible resin and spread on a support coated with a resinous material. The support is heated to cause the particles to be united thereto.

Abrasive stone holder. M. N. Prange. U. S. 2,000,611, May 7, 1935 (March 12, 1934).

Aluminum oxide abrasive and method of making. J. S. Masin (Swann Research, Inc.). U. S. 2,000,857, May 7, 1935 (Dec. 1, 1930).

Apparatus for applying abrasive to belts, polishing wheels, etc. J. S. Porter (D. & H. Scovil, Inc.). U. S. 1,998,905, April 23, 1935 (March 3, 1933).

Apparatus and method of determining tenacity of bonded granular bodies. R. L. Melton (Carborundum Co.). U. S. 2,001,794, May 21, 1935 (April 30, 1930). Apparatus for measuring the tenacity of bonded granular articles comprises a support adjustable to permit moving the article to be tested in a predetermined direction, means for moving a gouging tool to cut a groove in the article to a predetermined depth and along a nonrepeating path, the means comprising a driven shaft provided with a worm, a carriage slidably mounted in a frame and having a threaded connection with the worm shaft, a tool carrier slidably mounted in the carriage, and a means for measuring the force required to move the tool.

Buffing machine. F. E. Bertrand (United Shoe Machinery Corp.). U. S. 1,999,275, April 30, 1935 (May 31, 1933).

Centerless grinder. J. R. Dunham. U. S. 1,999,320, April 30, 1935 (March 18, 1932).

Disk-grinding machine. G. C. Leach and T. R. Leach. U. S. 1,998,783, April 23, 1935 (Nov. 10, 1933).

Feed and tail stock for grinding machines. J. R. Dunham. U. S. 1,999,321, April 30, 1935 (Feb. 15, 1933).

Grinding device. E. F. Lawhorn and S. R. Brenaman. U. S. 2,001,497, May 14, 1935 (June 15, 1934). A rotatable grinding device for shafts is described.

Grinding machine. W. D. Archea (Heald Machine Co.), U. S. 1,998,603, April 23, 1935 (Feb. 3, 1933). G. A. Carlson, U. S. 2,000,216, May 7, 1935 (July 1, 1933). A. W. Foerster and Clement Booth (Cincinnati Grinders, Inc.), U. S. 2,000,586, May 7, 1935 (Sept. 15, 1932). O. L. Griffin (Johnson Steel & Wire Co., Inc.), U. S. 1,998,755, April 23, 1935 (March 30, 1934). W. C. Osterholm, U. S. 2,000,667, May 7, 1935 (Dec. 11, 1931). E. G. Roehm (Cincinnati Grinders, Inc.), U. S. 2,000,614, May 7, 1935 (Nov. 22, 1933).

Grinding machinery. Willetts Peaslee and F. S. Haas (Cincinnati Grinders, Inc.), U. S. 1,999,778, April 30, 1935 (May 3, 1933). Willetts Peaslee and L. F. Nenninger (Cincinnati Grinders, Inc.), U. S. 2,000,608, May 7, 1935 (April 5, 1933).

Grinder or hone for cylindrical surfaces. J. E. G. Kline (Hutto Engineering Co., Inc.). U. S. 1,998,460, April 23, 1935 (Nov. 25, 1931).

Machine for plane-grinding piston rings. F. Isler. Brit. 426,759, April 25, 1935 (Sept. 7, 1933).

Manufacture of ceramically bonded abrasive articles. Carborundum Co., Ltd., and F. L. Nobes. Brit. 426,480, April 17, 1935 (Sept. 4, 1933).

Method and apparatus for grinding and polishing flexible sheets. Louis Schulte (Schulte Grinding and Polishing Machine Co., Inc.). U. S. 1,998,770, April 23, 1935 (Dec. 30, 1931).

Polishing, abrading, etc., devices. J. J. V. Armstrong (R. Bosch A.-G.) Brit. 427,252, May 1, 1935 (Sept. 15, 1933).

[1] The bold-face number following the journal is the volume, the issue number is in brackets, followed by the page numbers, then the year in parentheses.

Razor-blade grinding machine. WERNER TOBIAS (Aktiebolaget Tonsor). U. S. 2,001,117, May 14, 1935 (Nov. 26, 1932).

Reamer grinder. E. R. ZEITZ AND S. W. DENNISON. U. S. 2,001,173, May 14, 1935 (Nov. 3, 1931).

Spring suspension apparatus for vehicles. V. A. TRIER. Brit. 427,104, May 1, 1935 (Oct. 12, 1933).

Stone-shaping device. E. C. SMITH. U. S. 1,998,642, April 23, 1935 (Dec. 16, 1932).

Taper roller lapping device and method. W. E. HOKE. U. S. 2,002,317, May 21, 1935 (Nov. 17, 1933).

Tool for grinding valves. L. O. BEARD. U. S. 1,999,922, April 30, 1935 (Jan. 18, 1935).

Truing the grinding surface of grinding wheels of screw-thread grinding machines. F. TURRETTINI. Brit. 427,064, May 1, 1935 (May 24, 1934).

Valve-grinder dressing tool. F. O. ALBERTSON (Albertson & Co., Inc.). U. S. 1,999,435, April 30, 1935 (Feb. 19, 1934).

Valve-grinding machinery. C. I. LOTT. U. S. 1,999,198, April 30, 1935 (Nov. 21, 1933).

Valve-seat grinder. T. D. ENETE. U. S. 1,999,322, April 30, 1935 (Nov. 2, 1934).

Waterproof abrasive paper. CARL MUNCH (Atlas-Ago Chemische Fabrik, A.-G.). U. S. 2,000,532, May 7, 1935 (Oct. 19, 1933).

Waterproof sheet abrasive material and process for manufacturing. ATLAS-AGO A.-G. Brit. 427,627, May 9, 1935 (Oct. 6, 1932).

Art and Archeology

PATENTS

Coloring ceramic objects. HONORÉ BERETTA. Fr. 767,982, July 27, 1934; *Chem. Abs.*, **29**, 570 (1935).—A composition which gives beautiful black shades on firing contains alquifou 800, SiO_2 200, Mn 50, CuO 20, and Co 10 g.

Designs for:

Bathtub. J. R. MORGAN (Sears, Roebuck & Co.). U. S. 95,375 and 95,376, April 23, 1935 (Feb. 1, 1935).

Bottle. B. D. FUERST (United Distillers [of America], Ltd.), U. S. 95,672, May 21, 1935 (March 1, 1935). WILLIAM GUYER (Joseph E. Seagram & Sons, Inc.), U. S. 95,506, May 7, 1935 (Feb. 27, 1935). FRASIER SMITH (Hazel-Atlas Glass Co.), U. S. 95,462, April 30, 1935 (Feb. 11, 1935). J. S. STEELMAN (Black Prince Distilleries, Inc.), U. S. 95,556, May 7, 1935 (Feb. 25, 1935). J. S. STEELMAN (Whitall Tatum Co.), U. S. 95,464 April 30, 1935 (Feb. 7, 1935), and U. S. 95,555, May 7, 1935 (Feb. 21, 1935).

Glass jar. F. J. PETTY (Ball Bros. Co.). U. S. 95,607, May 14, 1935 (Aug. 28, 1934).

Glass plate, etc. G. S. DUNBAR (Federal Glass Co.) U. S. 95,579, May 14, 1935 (March 12, 1935).

Goblet, etc. W. C. MCCARTNEY. U. S. 95,366, April 23, 1935 (Jan. 3, 1935).

Jar. E. W. FUERST (Owens-Illinois Glass Co.), U. S. 95,674, May 21, 1935 (Oct. 31, 1934). L. P. GREY (Hazel-Atlas Glass Co.), U. S. 95,419, April 30, 1935 (Feb. 19, 1935).

Lavatory. J. R. MORGAN (Sears, Roebuck & Co.). U. S. 95,377 and 95,378, April 23, 1935 (Feb. 1, 1935).

Plate, etc. YUKIO BUMA (Morimura Bros., Inc.) U. S. 95,631 to 95,663, May 21, 1935 (Sept. 1, 1934). W. T. JOHNSON (Mayer China Co.), U. S. 95,431, April 30, 1935 (Feb. 14, 1935). B. N. KANE (Decal Products Co.), U. S. 95,689, May 21, 1935 (March 15, 1935).

Cements

Application of phase-equilibrium studies on the system CaO–Al_2O_3–SiO_2–Fe_2O_3 to cement technology. F. M. LEA. *Cement & Cement Mfg.*, **8** [2] 29–49 (1935).—The application to cement technology of constitutional work on Portland cement is discussed with reference first to the ternary systems $CaO{\cdot}SiO_2$–$5CaO{\cdot}3Al_2O_3$ and CaO–$2CaO{\cdot}SiO_2$–$4CaO{\cdot}Al_2O_3{\cdot}Fe_2O_3$ and then to the quaternary system CaO–$2CaO \cdot SiO_2$–$5CaO \cdot 3Al_2O_3$–$4CaO \cdot Al_2O_3$–Fe_2O_3. The phase-equilibrium diagrams are considered, and it is shown that the results on the quaternary system confirm the conclusions that have been drawn from the ternary systems regarding the compounds present in Portland cement. G.R.S.

Effect of granulometric composition of cement on the properties of pastes, mortars, and concretes. J. ARTHUR SWENSON, LACEY A. WAGNER, AND GEORGE L. PIGMAN. *Jour. Research Nat. Bur. Stand.*, **14** [4] 419–48 (1935); R.P. 777. Price 5¢. R.A.H.

Setting, hardening, and preservation of aluminous cements. HENRI LAFUMA. *Rev. mat. constr. trav. pub.*, No. 305, pp. 29–30 (1935).—The theory of aluminous cements is outlined with special attention to those aspects of the chemistry of aluminous cements which are still not well understood. M.V.C.

Standard cement. VIERI SEVIERI. *Tonind.-Ztg.*, **59** [19] 244–46 (1935).—A brief review is given of Italian standard specifications for cements and their testing. M.V.C.

Utilization of Mississippi low-grade bauxites. E. C. ECKEL. *Manufacturers Rec.*, **104** [2] 58 (1935).—In Mississippi, deposits of bauxite high in iron and silica have been considered of no commercial value. The T.V.A. will use them for producing high-grade alumina cements under U. S. patents 1,536,681, 1,536,683, and 1,591,662. The process makes it possible to obtain high silicon ferrosilicon, and the slags show less than 2% silica and 1% iron from a bauxite with as high as 30% of each. The cement made from the slag compares favorably with other alumina cements. E.J.V.

Enamels

Antimony in enamelware. W. DONOVAN. *Analyst*, **60**, 103 (Feb., 1935).—The annual report of the New Zealand Dominion analyst states that with several brands of enameled cooking utensils, dangerous amounts of Sb were dissolved from the enamel by acid foods. H.H.S.

Application of black-edging enamel. J. E. ROSENBERG AND A. LANGERMAN. Presented at meeting of Amer. Ceram. Soc., Buffalo, N. Y., Feb., 1935. *Ceram. Forum*, **1** [8] 2 (1935). M.C.S.

Cleaning castings by sandblasting. W. E. WARNER. *Metal Ind.* [London], **45** [2] (1934).—Suitable abrasive and proper air pressure make sandblasting an effective method of cleaning castings and forgings. Steel shot is more efficient and causes less wear on the nozzle. Large particles in sand tend to choke the nozzle and dust reduces the cleaning efficiency of the sand. The air pressure should be 80 lb./sq. in. for steel castings, 60 to 75 lb./sq. in. for gray iron castings, and 40 lb./sq. in. for brass and aluminum. H.E.S.

Cleaning before porcelain enameling. R. A. AMBISEN. *Enamelist*, **12** [7] 6 (1935).—The most efficient and least costly method of preparing metal for the application of porcelain enamel is alkali cleaning. E.J.V.

Enamel as protection for galvanized iron. L. VIELHABER. *Emaillerie*, **1** [10] 14–16 (1933); abstracted in *Emailwaren-Ind.*, **12** [9] 73 (1935).—In some cases it has been found advisable to enamel galvanized iron, mainly as a protection. For special pieces a durable enamel suitable to the shape is required. The composition should be adapted to the use of the object. M.V.C.

Evolution of the name tablet. ELECTROGRAPHER. *Metal Ind.* [London], **44** [5] 131–32 (1934).—The development of the name tablet is traced from the mid-Victorian period up to present-day cast-bronze and repoussé tablets. Two advantages of enamel, *i.e.*, legibility and cleanliness, are pointed out. H.E.S.

Factors in one cover-coat enamel. A. L. MATTHES. *Ceram. Ind.*, **24** [5] 276 (1935).—Important factors in the production of good one cover-coat enamel include minimum pickling in an agitated bath, maximum grinding time of the enamel, perfect ground coat with a uniform coating on all the ware, controlled specific gravity of the enamel, and proper atomization. A color matcher is essential in controlling the minimum and maximum variations in weight of the coating and the color of the enamel. E.J.V.

History and progress of Mullins Mfg. Co. H. E. MARTIN. *Enamelist*, **12** [7] 17–18 (1935).—Illustrated. E.J.V.

Improved methods in making model refrigerator. F. L. PRENTISS. *Iron Age*, **135** [14] 27–30 (1935).—Production of electric refrigerators by the Westinghouse Electric & Mfg. Co. has been sharply increased by (1) speeding up the final assembly line and putting additional workers on the line, (2) more rapid movement of parts through firing ovens made possible by increasing conveyer speeds and oven temperatures, (3) hanging work closer together on overhead conveyers, (4) rearranging press equipment for straight-line production, and (5) adopting new production methods that tend to cut down costs. New economies in the press shop include the use of universal dies quickly adjustable on universal bed plates for different sizes, reducing the number of dies required, the use of new metal-forming equipment, and the combination of operations on punch presses. Details and illustrations are given. A.K.

Kelvinator tells why porcelain excels. R. A. WEAVER. *Enamelist*, **12** [7] 4 (1935). E.J.V.

Maximum production from minimum of space. E. W. GOETZ. *Better Enameling*, **6** [4] 6–8 (1935).—Cribben & Sexton Co. has developed each series of operations so that they are self-contained. Illustrated. E.J.V.

Melting white enamels. M. F. SHUR AND V. I. MOZHEIKO. *Keram. i Steklo*, **11** [2] 19–21 (1935); for abstract see *Ceram. Abs.*, **13** [4] 84 (1934). M.V.C.

Porcelain enamel in the building industry. C. B. ROWLEY. *Enamelist*, **12** [7] 7–8 (1935).—Illustrated. E.J.V.

Porcelain enamel for interior decoration. M. J. SALTZMAN. *Better Enameling*, **6** [4] 10–11 (1935).—A porcelain enamel fireplace, table top, jardinière, and an indirect columnar light are used. Illustrated. E.J.V.

Porcelain enameled tile made on a mass-production basis. F. L. PRENTISS. *Iron Age*, **135** [19] 12–13 (1935).—Improvements in enameling and in its technology have contributed to the manufacture of this porcelain enameled product made by the Youngstown Pressed Steel Co. Details and illustrations are given. A.K.

Porcelain kitchen ware. J. B. NEALEY. *Iron Age*, **135** [17] 29–31 (1935).—Details are given of the manufacturing processes at the Strong Mfg. Co. Illustrated. A.K.

Process control and modern equipment in making refrigerators. KELVINATOR CORP. *Ceram. Ind.*, **24** [5] 285–88 (1935).—The Leonard Refrigerator Co. has strict control over all processes and every step is rigidly supervised. Illustrated. E.J.V.

Reconditioning pickling solutions. S. F. SPANGLER. *Iron Age*, **135** [15] 11 (1935).—In pickling steel products for enameling, the sulfuric acid weakens until, when spent, the solution consists of very weak acid and the ferrous sulfate formed from chemical combination of the consumed acid with the steel. A method for reconditioning not only eliminates the disposal problem of the spent solution but economically converts the spent liquor into strong sulfuric acid suitable for further pickling operations. The conversion is accomplished without the escape of fumes, without waste, and at a substantial money saving over other forms of disposal. A.K.

"Tepco" products step ahead. ENAMEL PRODUCTS CO. *Enamelist*, **12** [7] 9–10 (1935).—Illustrated. E.J.V.

Vitreous enamel industry in 1934. II. EMERSON P. POSTE. *Ceram. Ind.*, **24** [5] 300–306 (1935).—Under processing, P. takes up one-coat enamel, enamel preparation, fabrication of parts, and cold steel in enamel fog. New equipment and new uses of vitreous enamels as dedeloped in 1934 are described. Bibliography. For Part I, see "Porcelain—" *Ceram. Abs.*, **14** [6] 134 (1935). E.J.V.

BOOK

Enamels. A. I. ANDREWS. Twin City Printing Co., Champaign, Ill., 1935. 428 pp., 124 illustrations, 62 tables. Price $5.50. This is the first comprehensive text on vitreous enamels by an American author. The Fellows of the American Ceramic Society and the Porcelain Enamel Institute have given the book their endorsement. The text is a well-balanced technical treatise containing much valuable information for the shop man as well as for the technologist. It should be available to every person responsible for any phase of enameling and in every technical library. The subject matter is well arranged in twelve chapters and well indexed. The introductory statement gives the history of enameling. Two chapters present enamel raw materials and fundamental facts as to silicate equilibria, physical properties of enamel glasses, and opacity and color in terms of recent investigations. The table giving the physical and chemical data for raw materials is complete and well presented. The chapter on cast iron, sheet iron, and steel gives metallurgical and metallographic information which should not be overlooked since, in the enameling process, a metal is fused onto a silicate at temperatures involving structural changes in the stock. The preparation of metal surfaces for enameling is thoroughly treated in the light of modern practice and methods, giving a better understanding of the chemical factors in cleaning and pickling. The various methods of calculation and the types of enamel used for various purposes are presented. A set of charts for converting raw materials to equivalents reduces calculations to a minimum. Several tables of typical enamel compositions add to the usefulness of these chapters. The sections on shop practice (frit making, milling, application, and firing) offer an abundance of information, including methods of control that should be in use in every plant. The final chapter, "Enamel Properties and Tests," is an excellent compilation of methods and data regarding the physical and chemical properties of enamel. It also contains a summary of enamel defects and their causes. Practically all of the data needed by the enamel technologist and shop man is made available. The publishers have produced an excellent job of typography and binding, so essential to a reference book which is as frequently used as this one will be. E. P. POSTE

PATENTS

Enameling. G. CHAMPAGNE. Belg. 404,110, Aug. 31, 1934; *Chem. Abs.*, **29**, 2682 (1935).—The articles to be enameled are pickled, cleaned, coated with metal, dried, and coated with enamel.

Enameling iron. WALTER ECKHOFF. Ger. 602,244, Sept. 4, 1934; *Chem. Abs.*, **29**, 572 (1935).—A compound of Mg is added as a stiffening agent to a leadless enamel slip not containing clay, and the composition is applied wet to cast iron and then fired in known manner. A suitable composition is prepared by fusing a mixture containing quartz 11, borax 21, $BaCO_3$ 30.5, KNO_3 9.5, CaF_2 3, and feldspar 25%, grinding the product with addition of water, and adding up to 10% of MgO.

Enamels. EDMOND BANDELIER AND ARMAND ZURBRÜGG. Fr. 771,787, Oct. 16, 1934; *Chem. Abs.*, **29**, 1600–1601 (1935).—White malleable and unbreakable enamels are obtained on metal by coating the surface of the metal with a layer of fatty oil, sprinkling thereon powdered enamel so that the oil absorbs it, heating to 800 to 1000°, and repeating these operations as often as is necessary to obtain the desired thickness.

Enamels. IGNAZ KREIDL. Ger. 606,218, Nov. 27, 1934; *Chem. Abs.*, **29**, 1601 (1935).—In producing white enamel coatings, clouded by gas bubbles, with the aid of colloidal enamel slips containing clay, the luster of the coatings is improved by adding to the slip a small proportion of HCl or a chloride. Addition of 0.05 to 0.2% of NH_4Cl is suitable. See also Brit. 396,007, Aug. 2, 1933.

Ornamental panel, etc., of rustless steel and vitreous enamel. H. H. HARRIS. U. S. 2,001,725, May 21, 1935 (Oct. 21, 1931).

Preparation of iron or steel for enameling. JESSE J. CANFIELD AND GEORGE W. MCGOHAN (American Rolling Mill Co.). Can. 342,745, July 3, 1934; *Chem. Abs.*, **28**, 6268 (1934).—Iron or steel sheets from which the adhering mill scale has been previously removed by pickling in hot H_2SO_4 are submerged for 40 sec. in 8% HNO_3 solution at room temperature. The sheets are then scrubbed under running water, neutralized with hot 2% Na_3PO_4 solution, and dried by hot air. The sheets are etched by the HNO_3 to provide a better bonding surface for the enamel. The same results may be obtained by a variety of treatments in which the metal is subjected to a bath containing an oxidizing agent and an acid in the presence of a ferrous salt, whereby ferric salts are produced *in situ* which seem to be the effective etching agent. The bath should contain sufficient acid to prevent hydrolysis, *e.g.*, 5% of the stronger acids such as H_2SO_4 or HCl.

Glass

Angle of forking of glass cracks as an indicator of the stress system. F. W. PRESTON. *Jour. Amer. Ceram. Soc.*, **18** [6] 175–76 (1935).

Arrangement of inventiohs in glass technology in German patent classes. K. BOEHMERT. *Glastech. Ber.*, **13** [2] 41–46 (1935).—B. discusses the arrangement of inventions in glass technology under the different common classes into which German patents have been divided. Better arrangements are advocated. G.R.S.

Causes of the decreasing strength of glass with increasing load. K. H. BORCHARD. *Glastech. Ber.*, **13** [2] 52–57 (1935).—The influence of continuous loading on the strength of glass is shown by formulas. Besides the usual apparatus for measuring extension and compression, a device is described for measuring strength, resistance to loads, and extension. The breaking tension decreases with increasing continuous loading. The breaking process results from surface instabilities. The appearance of the fractured surfaces with different kinds of breaks is described. The relationship of strength to continuous loading is shown graphically. G.R.S.

Chemical changes in glasses caused by light and heat. J. HOFFMANN. *Glastech. Ber.*, **13** [2] 47–52 (1935).—Reports are given on sodium-silicate glasses containing iron

and arsenic, which are changed under the influence of ight to yellow, brownish-yellow, golden-yellow, and reddish-brown, and on antimony glasses which are changed to green. G.R.S.

Chemical durability of glass: plea for standard method of test. W. E. S. Turner. *Bull. Amer. Ceram. Soc.*, **14** [5] 165–69 (1935).

Chemical durability of glass: results of tentative test method. Committee on Chemical Durability of Glass. *Bull. Amer. Ceram. Soc.*, **14** [5] 180–84 (1935).

Coating glass plates with a stable and adherent glaze. E. Kahane. *Chim. & ind.*, **32**, 102 (1934).—The application of a paste of magnesium, zinc, or aluminum silicate on the surfaces of a plate of glass produces, after drying and heating under suitable conditions, a film which is continuous, opaque, stable, and adherent. As the glaze grips cementing agents, the plates of glass thus treated can be used in the same way as ceramic tile for the protection and covering of walls and floors and for tables for the kitchen and laboratory. M.V.C.

Constitution and color of iron-manganese glasses. W. Weyl and W. E. S. Turner. Read at meeting of Friends of the Kaiser Wilhelm Inst. for Silicate Research. Abstracted in *Tonind.-Ztg.*, **58** [94] 1145 (1934).—Earlier studies of the properties of iron-manganese glasses showed that in the presence of iron the color of manganese glasses is not affected in the way expected. On the basis of new studies with a series of glasses with a constant iron content but having an increasing manganese content, it was found that 3-valence manganese is unstable in the glass as long as traces of FeO are present. Thus, manganese displaces the oxidation equilibrium of iron. M.V.C.

Corrosion figures on glass. J. Herbert. *Chim. & ind.*, **32**, 102 (1934).—The constitution of glass can not be studied from corrosion figures formed upon it as these are only the impression of fluosilicates which were deposited because of their insolubility when the glass was attacked by hydrofluoric acid; a study of these compounds shows that glass is a homogeneous substance from a chemical point of view. See also *Ceram. Abs.*, **13** [11] 289 (1934). M.V.C.

Currents of thermal origin in glass tanks. Anon. *Verre & Silicates Ind.*, **6** [2] 23–25; [6] 106–108 (1935).—The origin and flow of currents in the glass mass during fusion are discussed. Since the quality of the glass depends to a large extent on these currents, it is necessary to know how they can be reduced to a minimum by proper construction of the tank. Literature on the subject is profuse but almost exclusively in German; a short résumé of the subject is given. M.V.C.

Decimal classification in *Glastechnische Berichte*. K. Fill. *Glastech. Ber.*, **13** [1] 16–17 (1935).—A special system of decimal classification of all articles appearing on glass was introduced in 1934. G.R.S.

Decolorizing of glass. I. Anon. *Glass*, **12** [1] 18 (1935). **II.** *Ibid.*, **12** [3] 114 (1935).—The quantity of sodium selenite, barium selenite, and zinc selenite necessary to neutralize iron tinting is dependent upon the melting temperatures, melting rate, and the time and temperature of annealing. Cobalt and manganese are invariably used in conjunction with selenium. **III.** *Ibid.*, **12** [4] 157 (1935).—The effects of arsenic, alumina, zinc oxide, sodium nitrate, boric acid, phosphoric oxide, and barium peroxide on the decolorizing properties of selenium are discussed. Arsenic is an effective decolorizer alone and is often used to suppress the amber tint imparted by selenium alone. The other ingredients are, in general, less effective than arsenic but in most instances tend to enhance the decolorization of the selenium. The time and temperature of melting and annealing are important factors in the control of decolorization. M.C.S.

Determining the origin of plate glass. F. H. Zschacke. *Diamant*, **56** [36] 422–24 (1934); **57** [1] 2–4 (1935).—When a sample of plate glass is treated with diluted hydrofluoric and sulfuric acid, a definite, etched picture is obtained according to the origin and after-treatment of the glass through grinding and polishing; from this picture the method of manufacture of the glass or whether the glass was treated subsequently can be determined. The treatment takes from 5 minutes to 1 day, depending on the type of glass. Flattened glass produced by the old method of mouth-blowing shows a structure of thin parallel lines produced by the action of the "flattening" wood on one side. "Lubber" glass shows a similar although more uniform structure. Fourcault glass shows fine parallel lines on both sides, running in the direction of drawing, which are probably due to the effect of the drawing nozzle. Glass manufactured according to the Pittsburgh method is the only plate glass showing no "etched" structure. Libbey-Owens glass shows lustrous spots on a dull underground (similar to oil in running water) on the side turned to the furnace. On both sides of ground and polished glass are innumerable fine bend lines which, under the microscope, resemble drop-like chains between which lie circular cavities. Rolled, drawn, and polished glass may be recognized through its striae which lie parallel to the surface. Drawn glass shows parallel striae perpendicular to the direction of drawing, while rolled glass shows wedge-shaped striae. M.V.C.

Electric conductivities for studying separations in molten glasses. M. A. Forx. *Compt. rend.*, **200** [13] 1100–1103 (1935).—Changes in electric conductivity are used to study in a continuous way (contrary to previously employed methods) modifications in compositions at varying temperatures or solid precipitations or separations in liquids. The method is exemplified by the investigation of separation in borocalcic solutions with increasing temperatures, of separations of tungstic oxide in boric oxide solutions by additions of lead oxide, and of separations of lead oxides in their solutions in boric oxide by additions of tungstic oxide. M.H.

Electrically heated furnaces in the glass industry and their economy. II. Cooling kilns. J. Horowitz. *Glashütte*, **64** [41] 671–73; [50] 819–21; [51] 836–38 (1934).—The electrically heated cooling kiln is more economical than any other type of kiln because of the simplicity of control and the fact that temperatures can be so regulated that any cooling curve can be established throughout its entire length. The theory of the cooling of glass and factors affecting the formation of stresses in glass are discussed. For Part I see *Ceram. Abs.*, **13** [10] 252–53 (1934). M.V.C.

Finding cracks in glassware. Theodore M. Miller. *Chemist Analyst*, **24** [1] 23 (1935).—Parallel wires attached

to an induction coil are run along the inside and outside of the glassware. A thick spark jumping between the wires locates cracks. A.P.

Glass, the molder of civilization. FRANCIS A. KEATING. *Ceram. Ind.*, **24** [5] 275 (1935).—The close relationship between the development of civilization and the development of glass is pointed out. Illustrated. E.J.V.

Glass technology in the 10th Century. W. THEOBALD. *Glastech. Ber.*, **13** [1] 1–7 (1935).—The writings of Theophilus on the early methods of glassmaking in Germany are reviewed. Descriptions of frit ovens, glassmelting furnaces, and glass batches are included. Later developments, such as the invention of the blowpipe and window-glass painting, are discussed. G.R.S.

Heating up glass tanks. J. GAVIN CALLINAN. *Glass Ind.*, **16** [5] 133–36 (1935).—While it is not difficult to heat up a tank without having a disaster, it is an exacting job to heat up a tank so that it will be in the best possible condition as to joints, cracks, iron-work, and contents when it is ready to produce. Details that can be taken care of before the fires are lighted are listed and suggestions for controlling the progress of the heating are offered. E.J.V.

Importance of Zschimmer's peak temperature in glass-melting. ANON. *Sprechsaal*, **67** [43] 655–56 (1934).—There was a difference of opinion regarding the best schedule for glassmelting, and the "peak temperature" system formulated by Zschimmer as a fundamental principle was not properly understood and applied. If provision is made for reaching the refining peak temperature at the proper point in the time schedule, the conditions of successful pot founding are reproduced in a continuous manner in a tank furnace of normal construction where the glass passes from charging end to working end in a certain period of time. M.V.C.

Insulating glass. THERMOLUX GLASS CO. *Can. Engr.*, **68** [17] 35 (1935).—Thermolux is a "sandwich" made of two pieces of thin-drawn sheet glass and a center layer of carefully disposed glass silk. The edges are sealed. Due to the glass-silk layer the light is diffused. The special properties of this glass are insulation against sun heat, directional light diffusion, conservation of indoor warmth, and elimination of glare. E.J.V.

Introducing sulfate into the batch in the mechanical production of Bohemian and bottle glass. A. A. TROUSSOV AND S. V. RODIN. *Keram. i Steklo*, **10** [2] 12–16 (1934); abstracted in *Chim. & ind.*, **32** [4] 856 (1934); *Chem. Zentr.*, ii, 2575 (1934).—From 30 to 35% of sodium sulfate (of the total quantity of alkalis) can be added to the batch. The salt introduced must be pure and contain not less than 96% Na_2SO_4. Sulfate is reduced only with charcoal or anthracite; the two materials must be intimately mixed. To insure the homogeneity of the glass, it is necessary to determine the ratio between the carbonate and the sulfate of sodium in the batch for given thermal conditions. This ratio must be carefully maintained. The use of a sulfate batch, however, affects the refractories more severely. M.V.C.

Measuring the viscosity of glass. F. H. NORTON. *Glass Ind.*, **16** [5] 143–44 (1935).—N. describes a new apparatus of high precision and simple construction for use in studies of glass viscosity. Illustrated. E.J.V.

Mechanical strength and transparency of glass paving blocks for use in glazed reinforced concrete. B. LONG. *Glastech. Ber.*, **13** [1] 8–14 (1935).—By suitable shaping and special quenching methods, a variety of glass paving block was made which is resistant to cracking and scratching. It meets the requirements for concrete in which it is embedded. Use of these glass blocks permits the development of structures of glazed concrete which heretofore were considered impractical. The increased lighting of the glass paving block depends partly on the shape of its side walls and partly on the polished metallic coating covering the walls. The increase in lighting is, in some cases, 80%. See also "Resistance—" *Ceram. Abs.*, **14** [5] 111 (1935). G.R.S.

Mirror making by the evaporating process. R. C. WILLIAMS. *Sci. Monthly*, **39** [3] 274–76 (1934).—Glass surfaces can be coated with metals by a process in which the metal is evaporated in a vacuum chamber and then condensed on a glass surface which is nearby in the chamber. The process is called the "evaporating process" and may displace the former process by which silver was chemically precipitated upon glass. At present about twenty-five elements have been evaporated including silver, gold, copper, aluminum, germanium, selenium, palladium, beryllium, etc. These surfaces have splendid properties of hardness, untarnishability, and reflectivity. A good history of the development of this process is given. H.E.S.

Old English glass. No. 59. The making of mirrors. FRANCIS BUCKLEY. *Glass*, **12** [3] 122 (1935).—A description of the procedure in the year 1688 is given. The French were the pioneers in this field. **No. 60. Ink horns and ink pots.** *Ibid.*, **12** [4] 155 (1935).—These glass containers for ink were small enough and of suitable shape to be carried on the person. They were used during the 17th Century. For No. 58 see *Ceram. Abs.*, **14** [6] 137 (1935). M.C.S.

Old Venetian glasses. ANON. *Glashütte*, **64** [52] 851–52 (1934).— Three hundred photographs of Venetian glasses were exhibited in Berlin in Nov., 1934, at the meeting of the Deutsche Glastechnische Gesellschaft. Characteristics of Venetian glasses of the 15th to 18th Centuries are described. M.V.C.

Osram Company machine glassworks. ANON. *Glas & App.*, **16** [1] 3–4 (1935).—The factory for the manufacture of incandescent lamps is described. A tank furnace for 130,000 kg. of molten glass supplies the material for 50,000 glass bulbs in 24 hr. M.H.

"Overflow-throat" type glass tank. R. T. HIPPS. *Ceram. Ind.*, **24** [5] 278–81 (1935).—The continuous glassmelting tank has a partial drop-throat type feed but the main feed is of the overflow-throat type, with the glass being carried vertically through the center of the bridge and then overflowing above the metal line into the working chamber. It has high melting efficiency, a fuel saving of about 47%, no seedy glass in three years' operation, flexibility, and constantly fresh glass as the working end is practically emptied every week. Color contamination from iron is eliminated if the optional drop-feed section of the throat is used. Highest quality refractories are used because of high temperatures obtained in the recuperator. The entire recuperator chamber is insulated as well as the

bottom and sides of the working chamber. Colored glass can be made by using the optional-throat features. E.J.V.

Pumice stone as a raw material for glass. ANON. *Glashütte*, **65** [2] 20–21 (1935).—Pumice stone was found suitable for use in the production of green or brown colored glass. As it is a porous substance, it melted readily and gave a homogeneous glass. The material sintered at 800° and melted to a green glass at 1150°. See also "Volcanic—" *Ceram. Abs.*, **14** [6] 138 (1935). M.V.C.

Pure gas—clear glass. ZIENER. *Glas & App.*, **15** [19] 147 (1934).—The importance of purified gas when working glass before the gas flame is pointed out as the only way the glass can be kept clear and white in the process. M.H.

Quartz glass and quartz-glass apparatus. M. GRIMM. *Glas & App.*, **15** [25] 207–209 (1934).—The various kinds of quartz occurring in nature and the processes of melting quartz and manufacturing articles from it are reviewed. M.H.

Recovery of loose grinding material. ZIENER. *Glas & App.*, **16** [2] 7–8 (1935).—A method of separating the still useful grinding material from the slime of the grinding process of glass is described. The expensive artificial grinding materials (silicon carbide, electrocorundum) can be recovered and used again. M.H.

Security of Peka glass. HUGO KÜHL. *Glashütte*, **64** [48] 787–88 (1934).—The superiority of Peka glass over safety glasses with intermediate layers of cellulose and artificial resin was shown by impact tests. Moreover, when Peka glass fractured, the fragments adhered securely to the intermediate layer because of the high elasticity and tensile strength of the latter. A pistol bullet fired at a distance of 6 m. only slightly dented a five-sheet Peka glass. Kämpfer was the inventor. M.V.C.

Shape: an important factor in the strength of glass. JAMES BAILEY. *Glass Ind.*, **16** [5] 137–41 (1935).—The more brittle a substance, the more necessary it is to consider the shape factor of strength. Glass is looked upon as an elastic substance capable of deforming under any applied load. Any sudden change in shape will result in a modification of the elastic behavior which tends to alter both the direction and the magnitude of the stresses. By a study of flexible models made of bakelite, phenolite, or celluloid, strains due to changes in shape, etc., may be determined and thus defects caused by shapes can be clearly shown. Strength and serviceability are dependent on shape as well as on inherent strength of the material. Coöperation between the artist, the mold designer, the artisan, and the management is required if shape defects are to be eliminated. Illustrated. E.J.V.

Silvering glass mirrors by cold method. G. HUTH. *Glas & App.*, **15** [25] 211 (1934).—The recipe and application are described in detail. M.H.

Silvering mirrors by cathode spraying. M. ROMANOVA AND G. POKROVSKIĬ. *Trans. State Opt. Inst.* [Leningrad], **10** [96] 1–4 (1934). M.V.C.

Testing pressure containers under sustained pressure. F. W. PRESTON. *Glass Ind.*, **16** [5] 147 (1935).—A simple method for testing ware under low sustained pressure, using sodium bicarbonate and sulfuric acid to produce carbon dioxide to exert the pressure, is described. By increasing the temperature of the water bath in which the ware is kept it is possible to increase the pressure. E.J.V.

Variation of the expansion coefficient of glass by annealing. NIUTA KLEIN. *Compt. rend.*, **200** [15] 1320–21 (1935).—The changes of the expansion coefficient of glass at room temperature as a function of previous heat treatment at temperatures from 300 to 1000°C were studied. The curves found are similar to those found by Lebedev for the changes of the refractive index; certain relations between the two exist which permit the calculation of the expansion coefficient from the index. It is pointed out that deformation of optical surfaces often ascribed to internal stresses might be due to expansion effects. M.H.

Vitreous state. G. HAGG. *Jour. Chem. Phys.*, **3** [1] 42–49 (1935).—The tendency of glassforming substances to supercool is discussed in connection with the existence of large or irregular groups in the melts of such substances. If the size of these groups makes their direct addition to the crystal lattice difficult and if the forces within them are strong enough to prevent a rapid disintegration of the groups, the melt will tend to supercooling and glass formation. In the inorganic glasses, consisting of oxides of metalloids or the corresponding acids or salts, the formation of large or irregular groups is caused by the strong tendency of these metalloids to coördinate oxygen in a definite way. If the number of available oxygen atoms is smaller than necessary for the formation of discrete polyhedral groups with the required coördination, the polyhedra will be linked together, sharing oxygen atoms. The resulting groups will delay crystallization and thus cause the formation of glass. G.R.S.

Vitreous state. W. H. ZACHARIASEN. *Jour. Chem. Phys.*, **3** [3] 162–63 (1935).—The general applicability of Z.'s theory for the structure of vitreous solids is given, and a comparison is made with Hagg's general theory (see preceding abstract). G.R.S.

Volatilization and the constituents of glass: Reply to recent criticism of G. W. Morey. ERIC PRESTON AND W. E. S. TURNER. *Jour. Amer. Ceram. Soc.*, **18** [6] 170–73 (1935). **Reply.** G. W. MOREY. *Ibid.*, pp. 173–74.

Volume coefficients of expansion of several gases at pressures below one meter. J. B. M. COPPOCK AND R. WHYTLAW-GRAY. *Proc. Roy. Soc.* [London], **143** [A850] 487 (1934).—The authors investigated the errors due to adsorption by the glass of the expansion bulbs. They are appreciable in the case of easily condensable gases. A.P.

Working lumophor glasses into luminous bulbs. W. TELLMANN. *Glas & App.*, **16** [3] 17–20 (1935).—To make illumination by luminous gases more like daylight or to produce more variety of colors, substances are added to the glass which become luminescent under the influence of the ultra-violet light of the enclosed vapor and transform the ultra-violet into visible light; if the glass of the tube is colored suitably, any desired color effect may be obtained. Tubes made according to this process (Ger. Pat. 583,305) have 180 to 370% higher luminosity than clear glass tubes. The manufacture of such tubes and the precautions to be taken are described. M.H.

World's oldest glass discovered. H. H. SLAWSON. *Glass Ind.*, **16** [5] 151 (1935).—A piece of clear blue glass,

with a specific gravity of 2.463 and a refractive index of about 1.515, was found at Tell Asmar, on the Euphrates River about 50 miles from Bagdad, in ruins of an old Babylonian city which dates back almost 5000 years. It is extremely clear glass and its age is surprising as it antedates Roman times when clear glass was introduced.

E.J.V.

BOOK

Glass industry in Italy (Industria del Vetro in Italia). MARIO BATTAGLIA. Ed. Soc. Editrice "Novissima," Rome, 1935. 341 pp. Price 35 L. Reviewed in *Centro Studi Ceram.*, **2** [2–3] 28–29 (1934–1935).—The origin and development of the art of glassmaking and a classification of the different branches of the glass industry are discussed in the first part of this work on the present importance of the glass industry in Italy. The production and commercial activity of the glass industry in Italy, the various branches of production, and the regulation of syndicates of this industry are considered. M.V.C.

PATENTS

Apparatus for:

Annealing window glass. J. H. FOX AND K. G. KUTCHKA (Pittsburgh Plate Glass Co.). U. S. 1,999,588, April 30, 1935 (March 17, 1933).

Continuous production of laminated glass. BERNHARD ENGELS. Ger. 605,739, Nov. 17, 1934; *Chem. Abs.*, **29**, 1954 (1935).

Conveying sheets of glass to annealing furnaces. FORGES ET ATELIERS DE CONSTRUCTIONS ÉLECTRIQUES DE JEUMONT. Fr. 43,904, Sept. 19, 1934; *Chem. Abs.*, **29**, 1599 (1935). Addition to Fr. 743,118, March 24, 1933; *ibid.*, **27**, 3794 (1933).

Cooling articles of glass. CORNING GLASS WORKS. Fr. 768,886, Aug. 14, 1934; *Chem. Abs.*, **29**, 568 (1935).

Cooling glass articles. CORNING GLASS WORKS. Fr. 770,119, Sept. 8, 1934; *Chem. Abs.*, **29**, 568 (1935).

Cutting glass. WILLIAM OWEN (Pittsburgh Plate Glass Co.). U. S. 1,999,594, April 30, 1935 (May 29, 1934).

Cutting glass sheets. C. F. BURDETT AND WILLIAM OWEN (Pittsburgh Plate Glass Co.). U. S. 1,999,586, April 30, 1935 (Aug. 16, 1930; Jan. 4, 1933).

Drawing glass tubes. CORNING GLASS WORKS. Fr. 773,237, Nov. 14, 1934; *Chem. Abs.*, **29**, 1598 (1935).

Making a fibrous product from glass. OWENS-ILLINOIS GLASS CO. Fr. 770,097, Sept. 6, 1934; *Chem. Abs.*, **29**, 568 (1935).

Making sheets of glass. CLARENCE P. BYRNES. Fr. 771,404, Oct. 8, 1934; *Chem. Abs.*, **29**, 901 (1935).

Molding glass under pressure. PILKINGTON BROS., LTD. Fr. 772,499, Oct. 30, 1934; *Chem. Abs.*, **29**, 1598 (1935).

Reheating or cooling glass objects. UNITED GLASS BOTTLE MANUFACTURERS, LTD. Fr. 773,299, Nov. 15, 1934; *Chem. Abs.*, **29**, 1598–99 (1935).

Tempering or annealing glass. CORNING GLASS WORKS. Fr. 769,947, Sept. 4, 1934; *Chem. Abs.*, **29**, 568 (1935).

Tempering glass. PILKINGTON BROS., LTD. Fr. 772,954, Nov. 9, 1934; *Chem. Abs.*, **29**, 1599 (1935).

Tempering glass objects. FRITZ ECKERT. Fr. 772,543, Oct. 31, 1934; *Chem. Abs.*, **29**, 1599 (1935).

Vertical drawing of sheets of glass. N. V. HOLLANDSCHE MAATSCHAPPIJ VOOR DE VERVAARDIGING VAN GLAS. Fr. 770,242, Sept. 11, 1934; *Chem. Abs.*, **29**, 568 (1935).

Apparatus and method for feeding molten glass. L. G. BATES (Hartford-Empire Co.). U. S. 1,999,749, April 30, 1935 (March 19, 1934).

Borax. AMERICAN POTASH & CHEMICAL CORP. Fr. 738,819, June 18, 1932; *Chem. Abs.*, **27**, 1999 (1933).—Crystalline borax is obtained by heating hydrated borax to a fused mass and withdrawing the mass from the heated zone immediately when fusion takes place and before the last traces of water have been removed. The cooling is carried out slowly and the escape of the water during crystallization produces a porous mass. An apparatus is described.

Ceramic-like products. N. V. MAATSCHAPPIJ TOT BEHEER EN EXPLOITATIE VAN OCTROOIEN. Fr. 771,639, Oct. 13, 1934; *Chem. Abs.*, **29**, 902 (1935).—Molten glass containing basic components is molded by the methods used in glassworking and, after solidification, the basic components are removed wholly or in part by water or aqueous solutions at high pressure and temperature. Products resembling ceramic products are obtained in this way.

Charge guide for glass feeders. E. H. CURTISS, JR. (Hartford-Empire Co.). U. S. 1,999,444, April 30, 1935 (Jan. 4, 1932).

Depositing substances on glass, etc. SOC. ANON. DES MANUFACTURES DES GLACES ET PRODUITS CHIMIQUES DE SAINT-GOBAIN, CHAUNY, ET CIREY. Fr. 772,023, Oct. 22, 1934; *Chem. Abs.*, **29**, 1598 (1935).—Glass and other vitreous or vitrified materials are heated to near the softening point and brought quickly to a temperature lower than that which corresponds to the lower limit of release of the tensions developed during manufacture, and substances or metal compounds are projected in the form of particles onto the glass, etc., at this lower temperature.

Electric glassmelting furnace. PAUL RICHALET. Ger. 608,152, Jan. 16, 1935; *Chem. Abs.*, **29**, 2680 (1935).

Electric glass-supply apparatus and method of controlling. H. A. WADMAN (Hartford-Empire Co.). U. S. 1,999,744, April 30, 1935 (Jan. 14, 1933).

Foraminous masses. TRIPLEX SAFETY GLASS CO., LTD., L. V. D. SCORAH, AND J. W. WILSON. Brit. 425,413, March 27, 1935 (Sept. 11, 1933).

Form for bending glass. L. V. BLACK (Pittsburgh Plate Glass Co.). U. S. 1,999,558, April 30, 1935 (Jan. 26, 1934).

Furnace for tempering glass. MANIFATTURA SPECCHI E VETRI-FELICE QUENTIN. Fr. 767,338, July 16, 1934; *Chem. Abs.*, **29**, 309 (1935).—Means for regulating the temperature are described.

Glass. FORGES ET ATELIERS DE CONSTRUCTIONS ÉLECTRIQUES DE JEUMONT. Fr. 766,275, Jan. 22, 1935; *Chem. Abs.*, **29**, 3479 (1935).—Means for transporting hot sheets of glass are given.

Glass. ALBERT KNAPP. Fr. 775,932, Jan. 12, 1935; *Chem. Abs.*, **29**, 3479 (1935).—The mass of glass, after fusion and refining, is cooled below the temperature at

which it can be worked and then reheated to that temperature by an electric current passed through the mass, so as to obtain a uniform temperature in all parts.

Glass. ALEXANDER F. MCNISH. Fr. 766,876, July 5, 1934; *Chem. Abs.*, **29**, 309 (1935).—Means for causing a circulation of molten glass in the collector of a glass furnace are patented.

Glassblowing machine. PATENT-TREUHAND-GES. FÜR ELEKTRISCHE GLÜHLAMPEN M. B. H. Ger. 605,646, Nov. 19, 1934; *Chem. Abs.*, **29**, 1953 (1935).

Glass-cutting apparatus. WILLIAM OWEN (Pittsburgh Plate Glass Co.). U. S. 1,999,593, April 30, 1935 (April 7, 1933; Sept. 21, 1933).

Glass and enamels. AMERICAN POTASH & CHEMICAL CORP. Fr. 771,108, Oct. 1, 1934; *Chem. Abs.*, **29**, 901 (1935).—Ordinary borax or partially dehydrated borates used in making glass and enamels are replaced by anhydrous crystalline $Na_2B_4O_7$ precipitated, *e.g.*, by Fr. 738,819 ("Borax," this issue).

Glassmaking furnace. FORGES ET ATELIERS DE CONSTRUCTIONS ÉLECTRIQUES DE JEUMONT. Fr. 769,923, Sept. 4, 1934; *Chem. Abs.*, **29**, 567 (1935).

Glassmaking furnace. SOC. ANON. DES MANUFACTURES DES GLACES ET PRODUITS CHIMIQUES DE SAINT-GOBAIN, CHAUNY ET CIREY. Fr. 767,990, July 27, 1934; *Chem. Abs.*, **29**, 567 (1935).—Construction of supporting brick for the roof is described.

Glass-molding apparatus. GLASFABRIK GERMANIA-HÜTTE BIENEFELD & CO. G.M.B.H. Ger. 605,645, Nov. 15, 1934; *Chem. Abs.*, **29**, 1953 (1935).

Glass permeable to ultra-violet rays. I. G. FARBENIND. A.-G. Fr. 43,722, Aug. 9, 1934; *Chem. Abs.*, **29**, 1598 (1935). Addition to Fr. 724,367.—The glass described in Fr. 724,367 and Fr. 43,500 (*Ceram. Abs.*, **14** [6] 139 (1935)) is found to be permeable to ultra-violet rays and is used for making incandescent and Hg-vapor lamps, etc.

Glass-shaping machines. A. W. PARFITT (Europäischer Verband der Flaschenfabriken Ges.). Brit. 426,467, April 17, 1935 (Aug. 23, 1934).

Glassware-takeout mechanism. A. J. SMITH (Hartford-Empire Co.). U. S. 1,999,742, April 30, 1935 (July 20, 1932).

Glass furnace. B. D. BROWN (Capstan Glass Co.). U. S. 2,001,766, May 21, 1935 (March 29, 1933).

Heat-resisting articles. ARCHIBALD G. MCLEAN. Australia 15,709/33, May 17, 1934; *Chem. Abs.*, **29**, 2681 (1935).—Rollers used in the manufacture of sheet glass and other heat-resisting articles are made from a composition containing asbestos fiber 85, Na_2SiO_3 10 parts, and water to form a paste.

Leer loader. J. W. ROSS (Hazel-Atlas Glass Co.). U. S. 2,001,332, May 14, 1935 (May 31, 1933).

Luminescent glass. GLASWERK GUST. FISCHER. Fr. 767,436, July 17. 1934; *Chem. Abs.*, **29**, 310 (1935).—An inorganic luminescent glass contains a sulfide of Zn, Ca, Ba, or Sr, separately or in any desired mixture, and compounds of one or more heavy metals such as Mn, Cu, Bi, Tl, Rb, Pb, Sb, Cd, or W, the metal being chosen according to the luminescent color desired.

Machine for flaring glass articles. H. R. SCHUTZ (Libbey Glass Mfg. Co.). U. S. 2,001,436, May 14, 1935 (March 25, 1933).

Making glass tubes. CORNING GLASS WORKS. Ger. 604,579, Oct. 27, 1934; *Chem. Abs.*, **29**, 901 (1935).

Means for circulating molten glass in furnace gathering basins. ALEXANDER F. MCNISH. Ger. 608,153, Jan. 16, 1935; *Chem. Abs.*, **29**, 2680 (1935). See Brit. 402,366, Dec. 6, 1933.

Method and apparatus for:

Feeding glass. A. E. HAMILTON. U. S. 1,998,616, April 23, 1935 (Oct. 31, 1932).

Forming hollow-glass articles. W. W. TRIGGS (Libbey Glass Mfg. Co.). Brit. 427,272, May 1, 1935 (Aug. 31, 1934).

Making glass. G. E. HOWARD (Hartford-Empire Co.). U. S. 1,999,761, April 30, 1935 (Oct. 24, 1932).

Producing curled or crimped glass wool. P. O. E. FRIEDRICH (Friedrich & Dimmock). U. S. 2,002,314, May 21, 1935 (Jan. 26, 1934).

Method of making glass. G. E. HOWARD (Hartford-Empire Co.). U. S. 1,999,762, April 30, 1935 (Jan. 18, 1933).

Method and means for delivering parisons to the finishing molds of glassforming machines. A. W. PARFITT (Europäischer Verband der Flaschenfabriken Ges.). Brit. 427,378, May 9, 1935 (July 21, 1934).

Method and means for surfacing glass. BERNARD LONG (Soc. anon. des manufactures des glaces et produits chimiques de St.-Gobain, Chauny et Cirey). U. S. 2,000-240, May 7, 1935 (Dec. 16, 1933).

Packaging of glass. W. F. BROWN (Libbey-Owens-Ford Glass Co.). U. S. 1,998,486, April 23, 1935 (May 9, 1932).

Plate glass transporting truck. LOUIS ROTHHOLZ. U. S. 19,580, May 21, 1935 (Feb. 18, 1935) reissue of U. S. 1,879-513, Sept. 27, 1932.

Press for making laminated glass articles. GLASHÜTTENWERKE VORM. J. SCHREIBER & NEFFEN. Austrian 139,204, Oct. 25, 1934; *Chem. Abs.*, **29**, 1590 (1935).

Process and apparatus for making flat glass. H. J. GALEY (Pittsburgh Plate Glass Co.). U. S. 1,999,562, April 30, 1935 (March 21, 1934).

Process and apparatus for drawing sheet glass. H. L. HALBACH (Pittsburgh Plate Glass Co.). U. S. 1,999,591, April 30, 1935 (Dec. 22, 1932).

Rollers for transporting drawn glass tubes or rods. N. V. MAATSCHAPPIJ TOT BEHEER EN EXPLOITATIE VAN OCTROOIEN. Ger. 608,333, Jan. 21, 1935; *Chem. Abs.*, **29**, 2680 (1935). This corresponds to Brit. 411,030, June 6, 1934.

Rolling glass bands. N. V. MAATSCHAPPIJ TOT BEHEER EN EXPLOITATIE VAN OCTROOIEN. Ger. 605,648, Nov. 15, 1934; *Chem. Abs.*, **29**, 1953 (1935).

Safety glass. LOUIS É. NOTTELLE. Fr. 43,705, Aug. 9, 1934; *Chem. Abs.*, **29**, 1599 (1935). Addition to Fr. 766,-344, June 26, 1934; *ibid.*, **28**, 7458 (1934).—A metal armature in the form of wires, bands, or gratings is introduced into the intermediate plastic layer. The armature may be ornamental.

Shaping the ends of glass tubes. JAKOB DICHTER. Ger. 605,837, Nov. 19, 1934; *Chem. Abs.*, **29**, 1953 (1935).

Shaping glass. J. F. MORSCHOLZ (Corning Glass Works). U. S. 1,999,525, April 30, 1935 (June 2, 1933).

Sight glass. A. O. AUSTIN (Ohio Brass Co.). U. S. 1,999,271, April 30, 1935 (Jan. 20, 1932). A sight glass for a liquid containing vessel and a thin metal diaphragm has one portion thereof sealed to the glass and another portion thereof sealed to the vessel to form a tight joint between the glass and vessel while permitting relative movement of the glass and vessel.

Tempering glass. HERZOGENRATHER GLASWERKE BICHEROUX & CIE, G.M.B.H. Fr. 775,205, Dec. 21, 1934; *Chem. Abs.*, **29**, 2681 (1935).—The liquid used for tempering is submitted to a strong agitation at the moment when the glass is immersed and while the glass is in the bath.

Tempering plate glass or sheets of any material. RAYMOND MEER. U. S. 1,999,337, April 30, 1935 (Oct. 18, 1934).

Transporting glass sheets from the rollers to the reheating furnaces. GLACERIES DE LA SAMBRE. Fr. 773,808, Nov. 26, 1934; *Chem. Abs.*, **29**, 1599 (1935).

Structural Clay Products

Brick at the Royal Academy. ANON. *Clay Prod. Jour. Australia*, **2** [4] 28 (Feb., 1935).—The Royal Academy in London has an architectural room in which beauty in brickwork is featured. H.H.S.

Brick, tile, hollow brick, and drain pipe in annular kilns. P. THOR. *Tonind.-Ztg.*, **59** [16] 202–204; [17] 212–13 (1935).—Methods for placing clay products in annular kilns are described in detail. Illustrated. M.V.C.

De-airing sewer pipe. MARION W. BLAIR. *Brick Clay Rec.*, **86** [4] 138 (1935).—After trying to make sewer pipe by feeding de-aired clay slugs to the pipe press with poor results, a new set-up was developed. The equipment consists of a de-airing chamber furnished with proper de-airing apparatus and a revolving shaft equipped with proper agitating and disintegrating knives. This apparatus not only exposes every particle of clay to the vacuum action but also conveys it toward a sealed chute leading to the clay cylinder of the press. Advantages obtained are improved quality of ware, greater crushing strength, lower absorption, and lower power cost. Illustrated. E.J.V.

Decorating by means of brick. GR. *Tonind.-Ztg.*, **59** [10] 126–30 (1935).—The use of brick for decorating purposes, such as monuments, tombs, churches, etc., by the ancients, in the Middles Ages, and in modern times is briefly discussed. Illustrated. M.V.C.

Diatomite and vermiculite, porous clay products. ANON. *Tonind.-Ztg.*, **59** [2] 14–15 (1935).—A discussion of three Russian raw materials, their principal properties and possible applications as lightweight building materials, as heat insulation, and as filtration media is given. M.V.C.

Drying brick. OTTO PHILIPP. *Tonind.-Ztg.*, **59** [20] 250–52; [21] 268–69 (1935).—The physical conditions of drying brick are presented. Two methods of drying are discussed: (1) with atmospheric air without increasing the temperature and with sufficient and changeable ventilation (fresh-air drying) and (2) with heated air and limited ventilation (artificial drying). Before beginning the removal of the water, the raw brick should be preheated to a temperature at which the drying process begins. Only then will drying proceed under the best physical conditions and in the shortest time. M.V.C.

Drying stoneware pipes. E. WETTIG. *Tonind.-Ztg.*, **59** [24] 302–305 (1935).—The effect of temperature, air motion, and air moisture was studied. Conclusions are as follows: (1) Drying in warm air with insufficient ventilation produces cracks, while stresses originate in the interior of the pipes. (2) Drying at lower temperatures, moving air, and high moisture content do not injure the ware, but it requires a longer time for drying. (3) The best results are obtained when drying at higher temperature with a good ventilation and low moisture. M.V.C.

Economic operation of brick plants. W. LEDER. *Tonind.-Ztg.*, **59** [9] 99–102 (1935).—The discussion is based on three examples from practice. M.V.C.

Effect of hardening temperature and hardening time on the strength of sand-lime brick. HUGO IPPACH. *Tonind.-Ztg.*, **59** [8] 88–92 (1935).—A maximum strength which depends on the hardening time is reached for every hardening temperature. For obtaining maximum strength, a short hardening time is necessary for high temperatures. M.V.C.

Grinding and drying in brick plants. W. NEUMANN. *Tonind.-Ztg.*, **59** [23] 289–92 (1935).—The properties of clays suitable for dry-pressing and their granulation are discussed in detail. The effect of cooling on the brick and the equipment used are described. Illustrated. M.V.C.

Observations on setting. L. R. WHITAKER. *Brick Clay Rec.*, **86** [4] 132–33 (1935).—In any system of setting brick in a kiln, the following points must be considered: (1) control of draft and heat distribution, (2) preventing brick from falling, (3) minimizing kiln marking, (4) color effect. Fuel savings can be effected by proper setting. For good settings a level kiln floor and dry brick are necessary; uneven setting causes bats. By setting in blocks, the irregularity due to unevenness of the kiln bottom can be confined to the individual block only. Some faulty methods of setting and suggestions for correcting them are discussed. Illustrated. E.J.V.

Properties of brick in relation to processes of manufacture. A. ZAIMAN. *Brit. Clayworker*, **44** [516] 24–30 (1935).—Z. discusses processes of manufacture, properties required of brick for interior use and for exterior use as well as those for below the damp-proof level and for heavy load-bearing purposes. He also discusses colors and textures, strength, size and shape, durability, laminations and cracks, and efflorescence. R.A.H.

Sewer pipe in Berlin, Germany. FELIX SINGER. *Clay Prod. Jour. Australia*, **2** [5] 23 (March, 1935).—S. states that for more than fifty years the Berlin authorities have used only the finest stoneware pipe. The only concrete pipe permitted is for rain water. H.H.S.

Sewer pipe: stoneware versus concrete. EDITORIAL. *Clay Prod. Jour. Australia*, **2**, 1–2, 8, 15–16 (Jan., 1935).—A Royal Commission in Sydney (N.S.W.) last year brought in an overwhelming finding in favor of stoneware. The Sydney Water and Sewerage Board uses only stoneware up to the limit of manufacture. Adelaide (S.A.) has now

ordered 24-inch stoneware pipe. Brisbane (Qd.), which had put in concrete, finds the concrete attacked by H_2S. H.H.S.

Soft-mud brick: reminiscences. HENRY C. KLEYMEYER. *Brick Clay Rec.*, **86** [4] 134–36 (1935).—The beginnings of the soft-mud brick industry at Evansville, Ind., in 1850 by the Suhrheinrich brothers are described. In the late 1860's and early 1870's it was often found more economical to transport the brick plant to the job site and make the brick there than to transport finished brick the same distance. The only advantages other types of brick have had over soft-mud brick are truer, straighter edges and color. Face brick were made for a time by re-pressing handmade brick to meet competition of dry-press brick. E.J.V.

BOOKS

Determination of thermal conductivity of building and insulating materials. D. L. TIMROT. State Energy Pub. House, Moscow and Leningrad, 1932. 120 pp. Price 1R 90k. After a general review of heat conductivity and heat transfer and formulas for their determination, T. describes the apparatus used for this purpose by Péclet, Forbes, Lees and Chorlton, Niven, Lamb and Wilson, Bayer-Guillon, Metz and Behm, Biquard, Nusselt, Groeber, Poensgen, Griffiths, Jakob, Van Rinsum, and Timrot. The testing of materials at high temperatures is briefly discussed and the tests on finished insulations, walls, etc., are dealt with. The dependence of thermal conductivity upon different factors is treated. Three tables are appended: (1) gives the volume weight and coefficient of thermal conductivity for 159 organic materials; (2) gives the same data for 150 inorganic materials; and (3) gives the same data and porosity for refractory materials at different temperatures. The book is a useful contribution to the subject. S. I. PERKAL

Vitrified tile and joints (Klinker und Fuge). OTTO MEYER. Ziegel & Zement, Berlin, 1933. 60 pp. Price 3.50 Rm. Reviewed in *Tonind.-Ztg.*, **59** [4] 50 (1935).—This book deals with the question of vitrified tile and mortar for joints with special regard to German standard specification DIN 105. M.V.C.

PATENTS

Light brick. HENRIK NIELSEN. Ger. 603,857, Oct. 9, 1934; *Chem. Abs.*, **29**, 902 (1935).—Crude clay is dried, pulverized, and intimately mixed with organic material such as sawdust, peat, coke, coal, etc., with a water content of 10 to 17%. The mass is then pressed into shape and fired.

Manhole and cistern construction. N. P. O'NEAL. U. S. 2,002,127, May 21, 1935 (Aug. 13, 1934).

Manufacture of brick, etc. G. E. ROGERS. Brit. 426,-44, April 17, 1935 (March 17, 1934).

Method of making cellular clay products. H. D. FOSTER (National Fireproofing Corp.). U. S. 2,001,664, May 14, 1935 (June 15, 1933).

Plant associated with brick, etc., kilns. J. DRYSDALE. Brit. 427,579, May 9, 1935 (Jan. 29, 1934).

Porous brick, etc. HARRY T. BELLAMY. Ger. 606,067, Nov. 24, 1934; *Chem. Abs.*, **29**, 1599 (1935). See Brit. 392,465, May 18, 1933; *ibid.*, **27**, 4896 (1933).

Tile. HENRY JANSEN (George L. Ashline). U. S. 2,000,565, May 7, 1935 (Oct. 18, 1933).

Refractories

Characteristics of some silico-aluminous refractory products. MARCEL LÉPINGLE. *Rev. mat. constr. trav. pub.*, No. 303, pp. 205–208 *B* (1934); No. 304, pp. 11–14 *B*; No. 305, pp. 28–31 *B* (1935).—The products of 42 European and American firms were examined chiefly as to their behavior on firing. The test pieces contained varying amounts of alumina up to 45 to 47%. Tables give data on the softening temperatures, etc., of the different samples, which are compared. See also "Properties—" *Ceram. Abs.*, **14** [5] 117 (1935). M.V.C.

Comparison of two methods for controlling the degree of conversion of silica brick. V. V. LAPIN. *Trans. Petrographical Inst. Acad. Sci.* [U.S.S.R.], **6**, 463–84 (1934).—Twelve samples of silica brick with different degrees of conversion were investigated by the microscopic and specific-gravity methods. Tables show data on the chemical composition, percentage of unchanged quartz, specific gravity, compressive strength, P.C.E., water absorption, and volume weight. L. concludes that the specific gravity does not increase with the decrease of degree of conversion as was assumed. Because of different porosity the specific gravity also decreases. The following conclusions were drawn: (1) The chemical composition of brick influences specific gravity, obscuring the actual degree of conversion. (2) The different mineralogical composition of its glassy bond (the presence or absence of minerals with comparatively high specific gravity, *e.g.*, pseudowollastonite, etc.) may increase the specific gravity of the brick, although not influencing its quality. (3) Specific gravity gives no indication of the character of conversion of quartz in silica brick. S.I.P.

Corrosion of silica brick. HUMIHIRA YOSHIKI. *Jour. Metals* [Japan], **4**, Nos. 1–2 (1934); *Chem. Abs.*, **28**, 7454 (1934).—The corrosion of silica brick in open-hearth furnaces is described. Below 1700° the cristobalite zone protects the inner surface of the furnace from the corrosive action, but above 1700° the cristobalite zone is badly corroded.

Determining the resistance of silicon carbide by the eddy-current effect. L. I. RUSINOV. *Zhur. Tekh. Fis.* [U.S.S.R.], **4**, 319–27 (1934); *Chem. Abs.*, **29**, 974 (1935).—To avoid contact resistance, the resistance of silicon carbide is measured by means of the heat effect of eddy currents induced in the powder for which the formula, $P = 8/5K^2H^2\nu^2R^2\sigma V\ 10^{-16}$ watt, was developed. The wave-length varied from 250 to 1500 m. The SiC powder, of mean radius R 0.06 and 0.25 cm., was obtained in a Dewar flask, and every precaution was taken to prevent heat losses. A specific resistance of 0.5 ohm/cm. was obtained. All results showed the correctness of the formula derived, indicating that there were no highly conducting particles between the grains of SiC. Upon calculating the constant, A, in the Sommerfeld equation of distribution, a value is found indicating that in SiC there is a dis-

tribution of electrons according to their energies, subject to the statistics of Boltzmann, which result can be used for the further study of the properties of SiC. See also "Researches—" *Ceram. Abs.*, **14** [5] 118 (1935).

Dispersion of mullite. MICHITAKA SAWATARI. *Mem. Ryojun Coll. Eng., Inouye Commemoration Vol.*, pp. 41–47 (1934); *Chem. Abs.*, **29**, 2481 (1935).—New determinations were made on two samples of artificial mullite containing 0.80 and 1.86% TiO_2. Mullite with n greater than 1.67 is most easily distinguished from sillimanite by measurement of the dispersions, which are about 0.02 and 0.01, respectively. See also *Ceram. Abs.*, **8** [6] 446 (1929).

Dunites in ceramics as substitute for talc. L. V. OMININ. *Keram. i Steklo*, **11** [2] 29–32 (1935).—The composition and properties of dunite and talc mixes are compared. Dunite can be introduced into ceramic mixes instead of talc in the manufacture of products having a dark body. The use of dunite in saggers to increase their refractoriness (cone 12) is not excluded. Dunites can be used in thermal ceramics as a lining for cement kilns and for second-rate refractories. See also *Ceram. Abs.*, **14** [1] 17–18 (1935). M.V.C.

Fireclay refractories for glassworks use. I. ANON. *Glass*, **12** [1] 8 (1935). **III.** *Ibid.*, **12** [3] 100 (1935).—A discussion of the classification of clays on the basis of plasticity and grain size is presented. **IV.** *Ibid.*, **12** [4] 148 (1935).—Drying and firing shrinkage, after-contraction (shrinkage after the installation of the refractories in the furnace), and thermal expansion are chiefly discussed. For Part II see *Ceram. Abs.*, **14** [6] 141 (1935). M.C.S.

Forsterite and other magnesium silicates as refractories. R. E. BIRCH AND F. A. HARVEY. *Jour. Amer. Ceram. Soc.*, **18** [6] 176–92 (1935).

Gas permeability and pore structure. H. IMMKE. Presented at meeting of Friends of the Kaiser Wilhelm Institute for Silicate Research. Abstracted in *Tonind.-Ztg.*, **58** [94] 1146 (1934).—It is possible to determine in every ceramic body the so-called figure of permeability which depends to a great extent on the shape and distribution of pores. Attempts to express this dependence numerically failed; therefore attempts were made to determine experimentally the effective "cross-section" for the gas transit. M.V.C.

Highly refractory silicon-carbide brick for boiler and industrial furnaces. CURT RÜHL. *Elektrisitätswirtschaft*, **33**, 18 (Jan. 15, 1934); *Met. Abs.*, **5**, 399 (1934); *Chem. Abs.*, **29**, 2678 (1935).—The resistance of SiC against scorification is stressed. By selection of proper binding materials, brick which contain 85% SiC can be made. These brick, however, are subject to attack by oxidizing gases. Favorable results with SiC brick are reported in enameling furnaces whose heating times could be halved. Data are given on compressive strengths and melting points in comparison with other refractory materials.

High-temperature insulation for industrial furnaces. V. N. ALLEN HUMPHREY. *Blast Fur. Steel Plant*, **23** [4] 267–68 (1935).—Methods of calculation given make possible accurate predictions on heat savings by insulation, return on the investment, and the most economical thickness to be used. For Part IV see *Ceram. Abs.*, **14** [6] 141 (1935). E.J.V.

Laying fire brick. A. C. HALFERDAHL. *Can. Chem. Met.*, **19** [4] 92 (1935).—The use of sheet-iron plates between brick in furnaces reduces mechanical and thermal spalling of the brick. A coating to prevent too rapid oxidation of the sheets is suggested, using an expanding cement to help key the structure together. E.J.V.

Linings for tin-smelting furnaces. ANON. *Brit. Clayworker*, **44** [516] 7–9 (1935).—Well-selected fireclay brick are almost universally used because they are neither highly acidic nor highly basic in quality. Where the tin ore is rich in antimony, ordinary fire brick do not suffice, and in such cases chromite is required for the lining of the beds and magnesite for the walls. R.A.H.

Mechanism of slag attack on refractory materials. J. H. CHESTERS. *Refrac. Jour.*, **11** [4] 179 (1935).—Microscopic studies of thin sections of slagged refractories are useful in determining the causes of failure or satisfactory resistance of the refractories to slagging action. Microscopic photographs demonstrate slagging action on various refractories. M.C.S.

Method for decreasing the porosity of melting tubes made of alumina. T. SATO. *Kinzoku-no-Kenkyu*, **11**, No. 2 (1934); *Chem. Abs.*, **28**, 7455 (1934).—The porosity of a melting tube of alumina decreases when a saturated aqueous solution of Al or Mg salt is filtered into the interior of the tube and then heated at proper temperatures. The temperatures at which $AlCl_3 \cdot 6H_2O$, $MgCl_2 \cdot 6H_2O$, and $Mg(NO_3)_2 \cdot 6H_2O$ change completely into oxides are, respectively, 345, 530, and 460°. The most effective solution for decreasing the porosity of the tube is that of $AlCl_3$. This treatment also increases the resistance of the tube to corrosion.

Microscopical investigation of bauxites. Z. N. NEMOVA. *Trans. Petrographical Inst. Acad. Sci.* [U.S.S.R.], **6**, 485–89 (1934).—Bauxites of the following chemical composition were investigated:

SiO_2	6.09	9.73	13.10	3.72
TiO_2	2.50	2.66	2.88	1.98
Al_2O_3	53.43	49.97	43.61	71.06
Fe_2O_3	24.09	6.49	2.93	2.26
FeO	0.89	19.07	24.31	6.99
MnO	0.07		0.01	
CaO	0.57	Trace	0.48	Trace
MgO	0.38	0.40	1.04	0.51
$K_2O + Na_2O$	0.54			
H_2O	0.68		0.26	
Ignition loss	10.90	12.08	11.78	13.47
	100.14	100.40	100.40	99.99

S.I.P.

Placer mining kyanite in Georgia. C. F. GREENE. *Brick Clay Rec.*, **86** [4] 131 (1935).—The placer deposit of kyanite lies in Habersham County, Ga., and is undoubtedly derived from kyanite schist. The kyanite and associated quartz are separated by the water or placer method, the quartz being floated off while the heavier kyanite settles to the bottom of the sluice. By making three such separations a product of approximately 90 to 95% kyanite is produced, the remainder being quartz. E.J.V.

Pneumatic ramming of tank blocks with a high grog content. K. G. LUPIN. *Keram. i Steklo*, **11** [2] 17–18 (1935).—Data on the properties of high-grade refractories

with a high grog content manufactured by pneumatic ramming in U.S.S.R. are given. M.V.C.

Properties of retorts for metallurgical processes. ANON. *Metal Ind.* [London], **45** [8] 173–76 (1934).—Refractory materials for retorts employed in the zinc and lead industries are highly important. Practical experience and research has shown fireclay materials to give the best results. They should have (1) thin walls, (2) resistance to corrosion and erosion, (3) resistance to abrupt temperature changes, (4) high thermal conductivity, (5) stability of shape and volume, (6) refractoriness to stand working temperatures of 2400 to 2550°F, and (7) impenetrability of zinc vapors and products of combustion. Other factors such as constitution of material, effect of iron oxide, silica, mechanical wear, etc., are discussed. H.E.S.

Quartzites containing iron, a mineralizer for silica brick. P. P. BUDNIKOFF AND V. M. BARIS. *Tonind.-Ztg.*, **59** [13] 165–66; [15] 191 (1935).—Tests showed that (1) quartzites containing iron are suitable mineralizers for silica brick and (2) an addition of up to 5% of such quartzites may be added if the Fe_2O_3 content corresponds to 2.75% of the total content of the silica brick. M.V.C.

Recent improvements in the physical properties of silica brick. II–III. SANDFORD S. COLE. *Blast Fur. Steel Plant*, **23** [4] 288; [5] 352–53 (1935); for Part I see *Ceram. Abs.*, **14** [6] 142 (1935). E.J.V.

Refractory industry and the Russian five-year plan. CARL HEINRICH PETERS. *Feuerungstechnik*, **23** [1] 7–8 (1935).—Data on the development of the Russian refractory industry in the next 5 years are given. M.V.C.

Refractory materials in white-metal flame furnaces. EDMUND R. THEWS. *Tonind.-Ztg.*, **59** [3] 30–32 (1935).—Practice shows that grog brick with an alumina content of 36 to 46% is the best refractory material for the bottom part of flame furnaces for melting white-metal alloys rich in lead. The refractory mortar used in these furnaces and conditions of melting are discussed. M.V.C.

Refractory minerals and materials. No. 30. ANON. *Refrac. Jour.*, **11** [4] 185 (1935).—The occurrence, properties, and uses of baddeleyite, a zircon mineral which fuses at approximately 2700°C and has a specific gravity of 5 7, are discussed. See also *Ceram. Abs.*, **14** [1] 16 (1935). M.C.S.

Refractory mortar mixes. A. BRANISKI. *Tonind.-Ztg.*, **59** [11] 143–44 (1935).—Reasons why mortar and concrete usually do not withstand temperatures over 530° are discussed. A patented method of producing monolithic refractory masonry developed by B. (Rumanian Pat. 23,362, Nov. 16, 1934) is briefly discussed. M.V.C.

Semi-dry pressing of grog brick. R. KIESPER. *Tonind.-Ztg.*, **59** [21] 265–67 (1935).—Semi-dry pressing has the following advantages over wet pressing: (1) It produces a homogeneous body of uniform strength and high resistance to temperature changes but without structural defects. (2) The brick holds its shape better because of a low total shrinkage, easy shaping with even surfaces, and sharp edges and corners. (3) The cost of manufacture is lower because of a lower amount of grog used. Various types of press are briefly discussed. M.V.C.

Softening temperature and common silico-aluminous refractory products. A. C. *Rev. mat. constr. trav. pub.*, No. 306, pp. 33–36*B* (1935).—This article is a commentary on the work by Marcel Lépingle (*Ceram. Abs.*, **13** [7] 184 (1934)), which is a comparative study of European refractory products and their requirements. C. notes that the relation between the alumina content and the actual softening temperatures is not that generally indicated and that, in addition to the alumina content, there are other factors to consider which can be ascertained only by tests. See "Characteristics—" p. 165, this issue. M.V.C.

Stability of spinels. H. ZUR STRASSEN. Presented at meeting of Friends of the Kaiser Wilhelm Institute for Silicate Research. Abstracted in *Tonind.-Ztg.*, **58** [94] 1146 (1934).—The possibility of using the heterogeneous phase reaction in the solid state to express the stability of crystalline materials is discussed. This method was used for the study of the chemical behavior of aluminates of bivalent metals, among which those crystallizing into spinel types are used in ceramics. To investigate the stability differences of two aluminates, the aluminate of a metal with the oxide of another is converted in solid state at 1400 to 1500°. Two types of reactions occur: (1) The raw and finished products do not form a mixed crystal, *e.g.*, $MgO{\cdot}Al_2O_3 + CaO \rightarrow CaO{\cdot}Al_2O_3 + MgO$. According to the phase rule, the reaction must proceed completely up to the disappearance of a phase. In this case, $MgO{\cdot}Al_2O_3$ is disintegrated, while $CaO{\cdot}Al_2O_3$ is the more stable aluminate. (2) Raw and finished products form mixed crystals in pairs, *e.g.*, $MgO{\cdot}Al_2O_3 + NiO \leftrightarrows NiO{\cdot}Al_2O_3 + MgO$. The reaction proceeds to a state of equilibrium with the formation of a spinel phase and an oxide phase, whereby the cation of the more stable aluminate is concentrated in the spinel phase. M.V.C.

Standards for refractory materials. Compiled by the COMITATO TERMOTECHNICO ITALIANO. *Centro Studi Ceram.*, **2** [2–3] 18–22 (1934–1935).—Tentative standards compiled by the Italian Thermotechnical Committee are given for refractory materials, *i.e.*, materials with a fusing temperature determined according to the C.T.I. standards above 1500° and having mechanical resistance at high temperatures. Standards for raw materials, finished refractories, and chemical analyses are included. The Committee invites suggestions for varying or adding to the data given which will contribute toward the compilation of the final standards. M.V.C.

PATENTS

Apparatus for making clay receivers for zinc-reduction furnaces. "BERZELIUS" METALLHÜTTEN-GES.M.B.H. (Franz Kettner and Erich Koch, inventors). Ger. 601,499, Aug. 20, 1934; *Chem. Abs.*, **29**, 569 (1935).

Carbon silicide. AURÈLE L. MINGARD. Fr. 716,899, May 11, 1931; *Chem. Abs.*, **26**, 2284 (1932).—A furnace is described for converting pieces of C to hard pieces of silicide having the same form by heating the C by an electric arc in the presence of Si.

Ceramic objects. DIDIER-WERKE A.-G. Ger. 602,827, Sept. 17, 1934; *Chem. Abs.*, **29**, 902 (1935).—In making objects from a dry mixture of chamotte and clay, the clay is moistened for molding by an electrolytic liquid.

Firing chamotte. FELLNER & ZIEGLER A.-G. Ger. 603,943, Oct. 10, 1934; *Chem. Abs.*, **29**, 902 (1935).—

Clay is powdered and heated to 1100 to 1300° in a rotating furnace.

Manufacture of alumina hydrate. ARTHUR FLEISCHER (Kalunite Co.). U. S. 2,000,939, May 14, 1935 (July 7, 1933).

Reducing refractory oxides. COMPAGNIE FRANÇAISE POUR L'EXPLOITATION DES PROCÉDÉS THOMSON-HOUSTON. Fr. 771,642, Oct. 13, 1934; *Chem. Abs.*, **29**, 903 (1935).—Oxides such as Cr_2O_3 are reduced by treating them with nascent H at a high temperature and under reduced pressure. The H may be liberated by heating a hydride or an alloy of H with a metal. Apparatus is described.

Refractory brick. DIDIER-WERKE A.-G. Ger. 607,070, Dec. 17, 1934; *Chem. Abs.*, **29**, 1954 (1935).—Dry refractory fat clay not containing chamotte or like diluent is intensively kneaded with a small proportion of water, which may contain an organic adhesive or a dispersing agent. The clay is then molded by stamping or pressing and the products are fired.

Refractory brick. DORTMUND-HOERDER HÜTTENVEREIN A.-G. Fr. 772,773, Nov. 6, 1934; *Chem. Abs.*, **29**, 1600 (1935).—A mass composed of about 90% lean materials, the granulation of which is approximately above 4 mm. 5, 3 to 4 mm. 12, 2 to 3 mm. 12, 1 to 2 mm. 10, 0.5 to 1 mm. 30, and below 0.5 mm. 31%, and about 10% of binding clay is fired. Short Fe rods which do not touch are incorporated in the mass.

Refractory brick. HERMANN WOLL. Ger. 608,072, Jan. 15, 1935; *Chem. Abs.*, **29**, 2682 (1935).—Use is made of chamotte, etc., of about the following granule composition: above 4 mm. 5, 3 to 4 mm. 12, 2 to 3 mm. 12, 1 to 2 mm. 10, 0.5 to 1 mm. 30, and below 0.5 mm. 31%. The chamotte is mixed with about 10% of binding clay and then converted in known manner into brick containing embedded short iron rods or iron wire.

Refractory material for use in metal castings and process for making. A. S. WEYGANDT (Grasselli Chemical Co.). U. S. 1,999,382, April 30, 1935 (June 13, 1932). The process of making a porous refractory resistant to moisture and high temperatures comprises mixing sand and a soluble silicate with a hydrated aluminum oxide and shaping and firing the mixture.

Refractory products. NON-METALLIC MINERALS, INC. Fr. 772,729, Nov. 5, 1934; *Chem. Abs.*, **29**, 1600 (1935). Refractory products in which the MgO is agglomerated by Ca ferrite are obtained by heating a mixture giving MgO, not more than 3% of SiO_2, a compound of the nature of Fe oxide, and CaO in amount equal to twice the amount of SiO_2 plus an additional amount sufficient to combine with the Fe oxide. Thus the mixture may contain SiO_2 1.2 to 2.2, Fe oxide 4.7 to 9.7, and CaO 5.5 to 10.4%. See also "Refractory synthetic—" *Ceram. Abs.*, **13** [9] 237 (1934).

Retaining means for fire walls of furnaces. A. C. PACIFIC. U. S. 1,998,733, April 23, 1935 (April 3, 1934).

Silicon carbide articles. AURÈLE L. MINGARD. Ger. 603,230, Sept. 25, 1934; *Chem. Abs.*, **29**, 570 (1935); see also "Carbon silicide," this issue.

Treatment of refractory brick for furnaces for annealing mirrors and special glasses. P. J. MALHERBE. Belg. 403,247, June 30, 1934; *Chem. Abs.*, **29**, 2682 (1935).—An intimate mixture of Na silicate, potash, and very fine emery powder is forced into the pores of the refractory to a depth of 2 to 3 cm.

Terra Cotta

Coating raw bodies with an engobe. ANON. *Ton-ind.-Ztg.*, **59** [3] 56–57 (1935).—Directions for applying colored engobe on raw bodies are briefly discussed.

M.V.C.

Manufacture of pipes and accessories in stoneware with salt glaze. A. COULHON. *Rev. mat. constr. trav. pub.*, No. 302, pp. 189–93*B*; No. 303, pp. 215–17*B* (1934); No. 304, pp. 7–11*B*; No. 305, pp. 23–27*B*; No. 306, pp. 40–42*B* (1935).—The manufacture of stoneware pipes with salt glaze is treated in detail as to the causes of the difficulties in this industry and their remedy. The raw materials, characteristics and compositions of clays, materials mixed with clay, and a commercial classification of clays are given.

M.V.C.

Scientific manufacture of stoneware tile. II–IV. F. CHALAMEL. *Rev. mat. constr. trav. pub.*, No. 302, pp. 193–98*B*; No. 303, pp. 208–212*B* (1934); No. 304, pp. 5–7*B* (1935).—Laboratory work is taken up as follows: (1) ceramic tests (the behavior of raw materials on firing), (2) physical analysis, (3) chemical analysis, (4) determining the plasticity, cohesion, and deformation of clays or clay mixtures, (5) petrographic examination, and (6) tests on the physical resistance. The difficulties of manufacturing stoneware tile are discussed. Then follows an examination of the raw material, clay: (1) the essential nature of clays for use in the manufacture of stoneware tile, (2) scientific methods of studying clays, and (3) data obtained by the use of the above methods. For Part I see *Ceram. Abs.*, **14** [3] 75 (1935).

M.V.C.

PATENTS

Filtering product and process of making. C. R. MINTON (William B. Phillips and Burdick R. Ells). U. S. 2,000,777, May 7, 1935 (April 18, 1933). A porous ceramic filtering body comprises siliceous particles of a splintery and feathery nature and a vitreous ceramic bonding material.

Glazing. AKT.-GES. FÜR INTERNATIONALE PATENTVERWERTUNG. Swiss 167,098, July 2, 1934; *Chem. Abs.*, **29**, 570 (1935).—A glaze resistant to weather, acid, and spirits is produced on walls, tile, etc., by coating these with a cold mixture of quartz, Sorel cement, Epsom salt, nitrocellulose, softening material, and solvent, allowing this to set, then applying a further coating of nitrocellulose, glyptal resin, and solvent, and giving a final coating of a hardening lacquer containing acetylcellulose.

Roof sump or floor drain. E. W. N. BOOSEY. U. S. 1,999,277, April 30, 1935 (Aug. 25, 1930).

Roofing tile. J. H. HUTCHINSON (Pipes, Ltd.), U. S. 2,000, 392, May 7, 1935 (Jan. 29, 1934). JULIUS KREMPER, U. S. 2,002,244, May 21, 1935 (Aug. 28, 1931). WILHELM LUDOWICI, U. S. 1,999,244, April 30, 1935 (March 16, 1933).

Roofing tile fastener. T. R. KOBE. U. S. 2,002,206, May 21, 1935 (Feb. 21, 1933).

Whiteware

Control of slip with the Kabus softness tester. HANS HECHT. *Tonind.-Ztg.*, 59 [10] 130–31 (1935).—Observations made with the Kabus softness tester on the consistency of various slips at the "Tonindustrie" chemical laboratory and the apparatus are described. The results are tabulated and plotted in curves. M.V.C.

Manufacturing electrical porcelain. ANON. *Clay Prod. News*, 8 [5] 3 (1935).—The factory of Smith and Stone, Ltd., where electrical porcelains, electrical refractories, and bakelite products are manufactured, is described. M.C.S.

Sintered corundum ware. F. H. W. LOEWE. *Glas & App.*, 15 [17] 133–34 (1934).—Sintered corundum is made into chemical apparatus, fixtures and fittings for electric furnaces, and electric insulating material where mechanical strength and resistance to chemical attack at high temperatures are required. It consists of almost pure Al_2O_3, 99.7%, begins to soften at 1730°C under 2 kg./cm.², and resists boiling 10 and 30% NaOH and water-vapor under 150 atmospheres, cold HF, phosphoric acid, soda and potassium melts, Na_2CO_3, and metals and alloys. M.H.

PATENTS

Ceramic products. SOC. ANON. DES MANUFACTURES DES GLACES ET PRODUITS CHIMIQUES DE ST.-GOBAIN, CHAUNY ET CIREY. Fr. 768,333, Aug. 3, 1934; *Chem. Abs.*, 29, 569 (1935).—Ceramic products having a certain degree of vitrification are tempered as glass is tempered.

Combination flatware and under reflecting surface. GEORGE KOLB. U. S. 1,999,195, April 30, 1935 (March 16, 1933).

Method of making dental porcelain. F. P. HOFFMAN (American Porcelain Co.). U. S. 2,000,285, May 7, 1935 (March 19, 1932). A method of making dental porcelain comprises fusing a preliminary mixture containing feldspar with silica, fusing the product from the first fusion step with a coloring agent, and fusing the colored mixture with feldspar and kaolin.

Porcelain. BRUNO BÖTTCHER. Ger. 601,500, Aug. 20, 1934; *Chem. Abs.*, 29, 570 (1935).—Finely ground crude kaolin is suspended in water, and the suspension is treated with an alkaline electrolyte. Impurities such as Fe_2O_3, TiO_2, and mica are thus precipitated, but the quartz and feldspar present remain in suspension. The suspension is then withdrawn, concentrated if necessary, and used in the manufacture of porcelain with or without the usual additions. Alternatively the sludge obtained in the ordinary process of refining kaolin may be ground and treated in aqueous suspension with an alkaline electrolyte to yield a suspension of quartz and feldspar, which are recovered and mixed with refined kaolin.

Porcelain. GIOVANNI FUSCHI AND MAURIZIO KORACH. Fr. 768,970, Aug. 17, 1934; *Chem. Abs.*, 29, 570 (1935).—Objects are made from a flowable mass freed from bubbles of gas by heating or reducing the pressure or both.

Pottery. DEUTSCHE TON- & STEINZEUG-WERKE A.-G. Ger. 604,747, Oct. 29, 1934; *Chem. Abs.*, 29, 902 (1935).—A method of raising the hardness of ceramic masses or metal carbides, etc., worked up by ceramic processes, consists in removing the gases from the capillary recesses of the dried masses by evacuation and kneading the mass with a suitable liquid without destruction of the vacuum.

Preparation of ceramic raw materials. DOULTON & CO., LTD., AND J. P. LORAINS. Brit. 426,662, April 17, 1935 (Nov. 15, 1933).

Spark plugs. ROBERT BOSCH A.-G. Fr. 772,601, Nov. 2, 1934; *Chem. Abs.*, 29, 1600 (1935). A ceramic product for spark plugs is composed of a difficultly fusible oxide, *e.g.*, corundum, and a binder which, during thermal expansion, behaves elastically toward the oxide used. The binder should become plastic at 500 to 800°. An example of a binder for use with corundum contains steatite or talc 32.7, kaolin 43.3, and feldspar 24 parts by weight.

Water-closet bowl with integral seat posts. M. D. HELFRICH. U. S. 1,999,905, April 30, 1935 (Sept. 3, 1931).

Equipment and Apparatus

Artificial drying and breaking caused by it. FR. REUMANN. *Tonind.-Ztg.*, 59 [15] 190–91 (1935).—Charts are plotted showing the effect of slow and rapid drying on clayware. M.V.C.

Automatic glazing machines for flat and semi-hollow tableware. SCHWEITZER EQUIPMENT CO. *Ceram. Ind.*, 24 [5] 294 (1935).—Two straight-line glazing machines designed and installed at the C. C. Thompson Pottery Co. are described. Illustrated. E.J.V.

Automatic printing of dinnerware, bottles, and glassware. ICHIRO HAKOGI. *Ceram. Ind.*, 24 [5] 290 (1935).—The Kurba Gravo is a fully automatic machine which prints by the offset process either from half-tones, intaglio, or lithograph in as many as six colors on pottery or glassware. The speed of the machine is 12 pieces per minute, and it is claimed that decorating costs will be reduced to about one-sixth that of average decal decoration. Illustrated. E.J.V.

Chambers method of de-airing. ANON. *Clay Prod. News*, 8 [3] 2 (1935). M.C.S.

De-airing of clay. H. SPURRIER. *Ceram. Ind.*, 24 [5] 272–74 (1935).—Experiments on de-airing clay bodies revealed that immediately following a thorough evacuation there must be a compression vigorous enough to compact the de-aired mass thoroughly. Laboratory determinations of moisture, penetration, and residual air in evacuated blocks are described. A volumeter for determining residual air in evacuated bodies is described. Illustrated. E.J.V.

Electrical distance thermometers. J. F. MARTIN. *Mech. World*, 97 [2520] 371–72 (1935).—The electrical resistance of a coil of fine wire changes with its temperature. This principle forms the basis of a system of remote temperature measurements suitable for the control of temperature in works, factories, etc. E.J.V.

Experimental investigation on the velocity of efflux of

granular mass. KOITIRO TAKAHASHI. *Sci. Papers Inst. Phys. Chem. Research*, **26** [540] 11–20 (1935).—A physical study of the velocity of sand falling through a hole in the bottom of a cylindrical vessel is given. J.B.A.

Heat-resisting alloys. W. F. FURMAN. *Ind. Heating*, **2** [4] 187–90 (1935).—Alloys used particularly in the petroleum industry are reviewed, different Cr-Ni alloys and the influence of C content are described, and applications are discussed in general. M.H.

Magnetic separation equipment. HARRY INGERSOLL. *Better Enameling*, **6** [4] 12–13 (1935).—Two inexpensive, effective separators of simple design, quickly constructed with a minimum outlay, are a trough with magnets in the bottom and a magnetic rake, both made of magnets from the fly-wheels of old model T Fords. Construction details are given. Illustrated. E.J.V.

Steele de-airing machine. ANON. *Clay Prod. News*, **8** [3] 8 (1935). M.C.S.

Suction filter for soot. F. VON VOPELIUS. *Glastech. Ber.*, **13** [1] 14–16 (1935).—Glass plants using regenerator gas heating often suffer from layers of dust being deposited in the gas conduits and channels. Since difficulties arise in the furnace operation by precautions taken to overcome this trouble, studies were made on a dust filter. Its construction and method of operation and the results and the advantages of its use are discussed. G.R.S.

Tests with vacuum presses. K. ZIMMERMANN. *Tonind.-Ztg.*, **59** [10] 123–26 (1935).—Results of tests are given in tables. A brick of a much greater strength and density is obtained when using a vacuum press; this, however, somewhat increases the danger of cracking the edges of the brick. M.V.C.

Working clay with machines in 1573. F. M. FELDHOUS. *Tonind.-Ztg.*, **59** [21] 270 (1935).—Screw presses used for manufacturing crucibles are briefly described. Illustrated. M.V.C.

PATENTS

Apparatus for molding ceramic structures. WILLIAM TAYLOR (James M. Teahan). U. S. 2,000,623, May 7, 1935 (July 20, 1931).

Ceramic masses. RICHARD RAUPACH MASCHINENFABRIK GÖRLITZ G.M.B.H. Fr. 768,828, Aug. 14, 1934; *Chem. Abs.*, **29**, 569 (1935).—Means for extracting air contained in the masses is described.

Kilns, Furnaces, Fuels, and Combustion

Advantages of complete cleaning of producer gas. JOSEPH MORANGE. *Glass*, **12** [3] 106 (1935).—The elimination of the tars and water-vapor from producer gas before it is consumed is essential for the efficient utilization of this type of fuel. Facts and figures included bear out this statement. M.C.S.

Dressler "thrift" muffle kiln at Smith and Stone, Ltd. ANON. *Clay Prod. News*, **8** [3] 9 (1935).—A small continuous, muffle kiln 110 ft. long, designed for firing bisque and once-fired glazed electrical porcelain, heater plates, etc., at cone 10, holds 16 cars. The kiln is equipped with two oil burners on a side that are of the low-pressure air-atomizing type. The heat from the cooling zone is utilized in preheating the air used for combustion. M.C.S.

Flue-gas composition in "Vlam-kilns." P. THOR. *Tonind.-Ztg.*, **59** [1] 3–4 (1935).—"Vlam-kilns," a chamber annular kiln with overhead flame for firing paving tile in the Netherlands, is briefly described. A curve showing the CO_2 content in the kiln is discussed in detail. M.V.C.

Furnace crowns. W. VÖLKEL. *Tonind.-Ztg.*, **59** [2] 16–17 (1935).—Various types of special furnace crowns and the refractory materials used for them, including grog, silica, magnesite, and chromite, are briefly discussed. M.V.C.

Physics and chemistry of firing ceramic ware. J. B. AUSTIN. *Bull. Amer. Ceram. Soc.*, **14** [5] 157–65 (1935).

Practice and firing difficulties in brick-plant operation (fired yellow brick). ALFRED SOERENSEN. *Lerind.*, No. 14, pp. 94–96 (1934); abstracted in *Tonind.-Ztg.*, **59** [9] 118 (1935).—Attempts to obtain brick of a uniform yellow color were successful when common salt was added to the fuel. M.V.C.

Rim-element electric furnaces for high temperatures. H. MASUKOWITZ. *Metal Ind.* [London], **45** [1] 11–15 (1934); for abstract see *Ceram. Abs.*, **13** [4] 96 (1934). H.E.S.

Round downdraft kiln of reinforced brick masonry. JUDSON VOGDES. *Brick Clay Rec.*, **86** [4] 128–29 (1935).—A 35-ft. beehive kiln was built with a 12-in. outer wall reinforced with horizontal and vertical rods, no outside bands being used. The space between the outer wall and the inner $13^1/_2$-in. firebrick wall was filled with 6 in. of diatomaceous earth. The kiln is designed to allow the fire brick to expand without affecting the structural wall or the crown. Illustrated. E.J.V.

Specific expenditure of fuel for firing and method of rating it. N. N. RUDNEV. *Ogneuporui*, **2** [11] 23–34 (1934). P.B. & E.S.

Thermal conductivity of air by a parallel plate method. E. O. HERCUS AND D. M. SUTHERLAND. *Proc. Roy. Soc.* [London], **A145**, 599 (1934).—A check was made on the hot wire method. The value found reduced to 0°C was 5.72×10^{-4} cal./cm./°C/sec., which is good agreement. A.P.

BULLETIN

Theoretical metallurgy II. High-temperature specific-heat equations for inorganic substances. K. K. KELLEY. *Bur. Mines Bull.*, No. 371, 78 pp. (1934). Price 10¢. This report represents a continuation of the study discussed in *Bull.*, No. 350. K. reviews the available high-temperature thermal data on inorganic compounds and gives representative specific-heat equations valid at high temperatures for use in thermodynamic calculations. A comprehensive bibliography is included. R.A.H.

PATENTS

Circular-type tunnel kiln and method of operating. P. D'H. DRESSLER AND E. A. HANFF (Swindell-Dressler Corp.). U. S. 1,999,356, April 30, 1935 (Sept. 15, 1933).

Electric furnace. W. I. ROBERTSON. U. S. 1,969,038, Aug. 7, 1934 (Aug. 8, 1930). V. H. SANDERS (Stackpole Carbon Co.). U. S. 1,969,478, Aug. 7, 1934 (Feb. 23, 1933).

Electrically heated tunnel kiln. SIEMENS-SCHUCKERTWERKE A.-G. Ger. 607,099, Dec. 17, 1934; *Chem. Abs.*, **29**, 1954 (1935).

Kiln for making roofing tile. RICHARD FRANZMEIER. Ger. 605,829, Nov. 19, 1934; *Chem. Abs.*, **29**, 1954 (1935).

Terminal for electric heating appliances. A. H. HEYROTH (Globar Corp.). U. S. 1,969,132, Aug. 7, 1934 (July 16, 1932). An electric furnace with a silicon carbide resistor has siliconized end portions, a water-cooled contacting member for conducting an electric current to the resistor, and an insert of Al interposed between the contacting member and the end of the resistor to avoid arcing.

Geology

Ammonium-carbonate method of dispersing soils for mechanical analysis. A. N. PURI. *Soil Sci.*, **39** [4] 263–70 (1935).—The ammonium-carbonate method of dispersing soils for mechanical analysis consists in boiling the soil with *N* ammonium-carbonate solution and continuing the boiling after the addition of NaOH or LiOH. The method was shown to give maximum dispersion with all types of soils including laterite and humus. G.R.S.

Anorthite from California. FRANKLIN S. MILLER. *Amer. Mineralogist*, **20** [3] 139–46 (1935).—A remarkably uniform anorthite is described. The optical properties and the chemical analyses of the mineral and the rock in which it occurs are given. A.K.

Borax. G. H. MCINTYRE. *Enamelist*, **12** [7] 24–25 (1935).—Borax is found in the form of tincal, ulexite, colemanite, Rasorite, or Kernite, from which the product is refined by a series of carefully controlled evaporations. Its chemical and physical properties are discussed. Illustrated. E.J.V.

Crystal structure of diaspore. F. J. EWING. *Jour. Chem. Phys.*, **3** [4] 203–207 (1935).—The parameters in diaspore were redetermined, and the structure was discussed from the standpoint of the coördination theory. The existence and location of hydrogen bonds in the structure were established and representative formulas were proposed. G.R.S

Distribution of Ordovician altered volcanic materials and related clays. G. MARSHALL KAY. *Bull. Geol. Soc. Amer.*, **46** [2] 225–44 (1935).—K. discusses the stratigraphic distribution of altered volcanic materials and related clays and the correlation of the formations that include them. Volcanism prevailed in varying intensity during Chazyan and Mohawkian epochs along the western margin of Appalachia. The Mohawkian volcanic materials that were ejected are distributed through formations ranging in age from Lowville to Sherman Fall. The relatively great thickness of altered volcanic rocks in southwestern Va. suggests that an active center of volcanism was in the adjacent crystalline region of N. C.; there may have been other volcanic regions farther to the north. The ash beds have been recognized in sixteen states and the province of Ontario, in regions as distant as Vt., northern Mich., Minn., and Mo. A.K.

Geological factors affecting clayworks. EDGAR MORTON. *Brit. Clayworker*, **44** [516] 20–22 (1935).—M. deals briefly with (1) variation in raw materials in relation to pit development, and (2) water supply to the clayworks. R.A.H.

Influence of potash-feldspar component on optical properties of the plagioclases. I. Mallard formula and its modification for three components. K. CHUDOBA AND F. DAVID. *Neues Jahrb. Mineral. Geol., Beil.-Bd.* **67A**, 196–216 (1933); *Chem. Abs.*, **28**, 6397 (1934).

Mineralogy and phase-rule studies. ERNST JÄNECKE. *Fortschr. Mineral., Krist., Petrog.*, **17**, 73–111 (1933); *Chem. Abs.*, **28**, 7203 (1934).—A discussion of anhydrous binary, ternary, and quaternary systems, illustrated by examples of mineralogic importance, especially the system CaO–MgO–Al_2O_3–SiO_2, is given.

Mining and refining of rocks and minerals for use in the German glass and ceramic industries. ANON. *Glashütte*, **65** [1] 7 (1935).—A research institute has been established at Koethen to investigate possibilities and give practical advice to producers and users of raw materials (principally clays and feldspars), primarily with a view to cutting down on foreign importation of supplies and substituting, where possible, products of purely German origin. M.V.C.

Properties of some American kaolins and comparison with English china clays. T. A. KLINEFELTER AND W. W. MEYER. *Jour. Amer. Ceram. Soc.*, **18** [6] 163–69 (1935).

Saskatchewan industrial minerals. W. G. WORCESTER. *Can. Mining Met. Bull.*, No. 277, pp. 239–50 (1935).—Lignite, salt cake, and clay are produced. Gas and oil exploration is in progress. There are interesting deposits of volcanic ash, salt, bentonite and colloidal clays, marl, ocher, sand, and gravel. G.M.H.

"Schluff" clays. BRUNO SPITTA. *Tonind.-Ztg.*, **59** [9] 105–107 (1935).—Clays containing finely powdered quartz or rock are called "schluff" clays. The mineralogical composition and rational analysis of such clays are given. Their working is discussed in detail. M.V.C.

Simpler method of expressing the mechanical analysis of many common soils. R. L. JAMES. *Soil Sci.*, **39** [4] 271–75 (1935).—Nearly every soil (material passing $^1/_8$-inch sieve) exhibits a regular grading in the size of its particles from coarse to fine. This grading permits the mechanical analysis of each soil to be represented logarithmically by a straight line to an accuracy within the limits of experiment and well within the limits demanded by the engineer. G.R.S.

Soil sampling instrument. A. LODDESOL. *Soil Sci.*, **39** [4] 257–61 (1935).—To fulfill the demand for exact sampling and for a definite determination of specific gravity, a special instrument was constructed for taking samples of organic soils and another for mineral soils. Dimensions, drawings, and photographs of the sampler are given. G.R.S.

Volume, shape, and roundness of quartz particles.

HAKON WADELL. *Jour. Geol.*, **43** [3] 250–80 (1935).—W. deals in detail with the presentation of new methods of measuring the volume, shape, and roundness of sedimentary quartz particles. A.K.

BOOKS AND BULLETINS

Clay (revised). PAUL M. TYLER. *Bur. Mines Information Circ.*, No. 6155, 66 pp. Free. This circular summarizes information on clay deposits, mining and preparation methods, manufacture of clay products, imports and exports, and prices. It also includes a general bibliography and a bibliography by states. See *Ceram. Abs.*, **8** [11] 848 (1929); **14** [4] 100 (1935). R.A.H.

Experimental study of the weathering of silicate minerals. OLOF TAMM. *Arkiv Kemi Mineral. Geol.*, **11A**, No. 14, 27 pp. (1934); *Chem. Abs.*, **28**, 6396 (1934).—By rotating hard minerals in C_6H_6 or H_2O, they can be reduced to particles of about 1μ. Particles produced by grinding quartz glass show a decided buffer action against KOH at about p_H 8, but 1 g. reacts with only 0.7 cc. of 0.1 *N* KOH. They retain about 1% H_2O at 105°. Feldspar particles, ground in C_6H_6, absorb 5 to 6% of their weight of H_2O from the air and retain it at 105°. They are partly decomposed by H_2O, which attains a maximum p_H of 10.76, K ions and silicate ions going into solution. The K silicate is 28% hydrolyzed. The undissolved residue takes up H ions which are partially freed by adding a neutral salt. The particles show a strong buffer action against H ions in the p_H range 10 to 6. Feldspar particles ground in H_2O exchange K ions for H ions in the p_H range 10 to 6, and a strong buffer action against H ions appears in the range 6 to 3; 1 g. takes up 20 cc. of 0.1 *N* HCl, and this indicates 15% decomposition. Muscovite particles, ground in C_6H_6, are also decomposed at p_H 6 to 3, and there is a reversible exchange of ions at p_H 10 to 6. It appears that the lattice of the feldspar in contact with H_2O is rearranged to form a muscovite lattice. Stilbite, a typical zeolite, gives particles which react reversibly in the range 9 to 6 and are decomposed below p_H 6. Wollastonite ground in H_2O shows a strong buffering against H ions. Its solubility in H_2O is 0.245 g. per liter at 18°. The p_H of the solution is 11.36, and its specific conductivity, 6.36×10^{-4}. The dissolved silicate is 57% hydrolyzed.

Kyanite and vermiculite deposits of Georgia. LOUIS M. PRINDLE *et al.* *Geol. Surv. Ga. Bull.*, No. 46, 50 pp., 11 plates, 4 figs. A survey of the kyanite reserves of Ga., conducted during the summer of 1934 by the U. S. Geological Survey in coöperation with the Ga. Division of Geology, led to the discovery of wide areas of a kyanite-bearing mica schist and isolated areas of kyanite in other forms and occurrences such as dornicks, placers, and in quartzite. The record of all properties visited for this survey and for previous examination is given. The kyanite is found in the Piedmont area which is bounded by the Fall Line to the south and the Cartersville Fault to the northwest. The only areas producing at present are in Habersham County in northeast Ga. and these properties are part of a U-shaped belt extending over into Rabun County and having an overall length of about 30 miles and a width of 1000 ft. or more. The average kyanite of the schists runs about 3% iron and 3% silica, but the placers yield a product containing only about 1% iron. The Bureau of Mines is conducting experiments concerning the beneficiation of the schist material and predicts that this can be recovered and used when there is sufficient demand. The vermiculite resources of Ga. have been only partly examined. The most promising deposits are in Towns County, near the N. C. line. This bulletin is sent free on receipt of postage by the State Geologist, 425 State Capitol, Atlanta, Georgia. The shipping weight is two pounds. LANE MITCHELL

Laboratory method of physical and historical geology. KIRTLEY F. MATHER AND CHALMER J. ROY. xiii + 302 pp., 46 figs., 20 plates, 1 map. Paper binding. D. Appleton-Century Co., New York, 1934. Reviewed in *Bull. Amer. Assn. Petroleum Geol.*, **19** [3] 418 (1935). G.M.H.

Materials manual of the silicate industry. V. V. TERNOVSKI. State Chem.-Tech. Pub. House, Leningrad, 1933. 300 pp. Price 4R 25k. This is a textbook dealing with minerals and rocks, foundations of chemistry, fuels, limes, and plasters, their manufacture and properties, quartz rocks and products made of them, clay and clay products, and cement and cement products. A subject index is appended. Illustrated. S. I. PERKAL

Sodium sulfate. PAUL M. TYLER. *Bur. Mines Information Circ.*, No. 6833, 39 pp. Free. T. describes uses, domestic deposits, foreign industry, and manufacture of sodium sulfate, which is particularly in demand by the paper and glass industries. Its three commercial forms are anhydrous sodium sulfate, salt cake, and Glauber's salt. R.A.H.

Summary of drifting and cross-cutting cost data. C. F. JACKSON. *Bur. Mines Information Circ.*, No. 6825, 14 pp. Free. Information collated from 33 information circulars covering as many mines is tabulated. R.A.H.

PATENT

Treatment of argillaceous material. PAUL MCMICHAEL (Allied Process Corp.). U. S. 1,999,773, April 30, 1935 (Jan. 3, 1933). A method of treating argillaceous material such as kaolin comprises suspending finely disintegrated argillaceous material in air and subjecting the material in suspension to the action of a bleaching agent of the group consisting of chlorine, hydrogen chloride, and sulfur dioxide. After the above steps the material may be suspended in an aqueous medium and subjected to the action of a dilute acid.

Chemistry and Physics

Alpha-nitro-β-naphthol as a precipitant for cobalt and for palladium. C. MAYR. *Z. anal. Chem.*, **98** [11–12] 402–408 (1934).—α-nitro-β-Naphthol precipitated as described by Stenhouse and Groves can be used instead of α-nitroso-β-naphthol to precipitate cobalt and palladium. Because they worked in the presence of hydrochloric acid, Hufeld and Gungross found difficulty in obtaining precipitates corresponding exactly to the formula $(C_{10}H_6ONO_2)_3Co$. The following procedure is recommended to obtain complete precipitation of the cobalt: To the solu-

tion containing a little mineral acid and 1 to 30 mg. of cobalt, add 10 to 20 cc. of perhydrol and then sufficient sodium hydroxide to precipitate all of the cobalt as cobalt hydroxide, avoiding an excess. Dissolve the precipitate by adding 10 cc. of glacial acetic acid and dilute with hot water to 150 to 200 cc. Add about 50% in excess of the reagent, stir, and heat to boiling. After the precipitate has settled, filter through a porcelain crucible. Wash three times with 30% acetic acid and finally with hot water. Dry at 130° and weigh. To prepare the reagent, dissolve 2 g. of the solid in 100 cc. glacial acetic acid, dilute the solution with 100 cc. hot water, and filter. The solution keeps much better than that of the corresponding nitroso compound. To determine cobalt in the presence of a little iron, the latter must first be removed with cupferron. If much iron is present, as in the analysis of cobalt steel, the iron, chromium, tungsten, molybdenum, titanium, copper, and silicon are removed by treatment with zinc-oxide suspension at the boiling temperature. In the presence of nickel, zinc, manganese, etc., it is necessary to have more acetic acid present when the cobalt precipitation takes place. A similar procedure serves to precipitate palladium in the presence of platinum. See also *Ceram. Abs.*, **12** [4] 173 (1933). E.J.V.

Calcium carbonate in ceramics. ALIX CORNILLE. *Rev. mat. constr. trav. pub.*, No. 305, pp. 17–20*B* (1935).—The action of calcium carbonate in terra cotta, faience, stoneware, porcelain, and enamel is explained. The purpose for which it is intended determines what per cent of impurities may be contained in the lime. The wet and dry treatments of calcium carbonate are quoted from *Rev. sci.*, No. 17, p. 572 (1934). M.V.C.

Change from liquid to glassy state. H. EBERT. *Glastech. Ber.*, **13** [3] 73–79 (1935).—The transformation point of glasses has considerable theoretic significance. No clear decision can be rendered on whether, by the appearance of the transformation point, a conversion to a higher species is shown. G.R.S.

Collation of experimental data. XIX. A. ALISON. *Glass*, **12** [3] 111 (1935).—A. describes the normal probability curve and its applications. **XX.** *Ibid.*, **12** [4] 164 (1935).—The use of the normal curve for expressing various data and the method of interpreting data thus represented are discussed. For Parts XVI to XVIII see *Ceram. Abs.*, **14** [6] 150 (1935). M.C.S.

Crystal classification and symbolism. D. JEROME FISHER. *Amer. Mineralogist*, **20** [4] 292–306 (1935).—Crystals are classified according to increasing symmetry into 2 phyla (axial and axihedral), 3 divisions (trimetric, dimetric, monometric), 6 systems, 7 systems and subsystems, 7 families (monaxial, polyaxial, anastrephaxial, orthaxihedral, monaxihedral, mesaxihedral, and polyaxihedral), 14 orders (rows), and 32 point groups or classes. In addition attention is called to 3 diagonal rows which, however, embrace only 20 of the crystal classes. The Manguin system of symbolism for both space and point groups and the Schoenflies method are briefly recapitulated. The former is recommended. A.K.

Determination of carbon dioxide in carbonates. HENRY B. KELLOG. *Chemist Analyst*, **24** [2] 4 (1935).—K. draws out residual CO_2 by aspiration of air freed from H_2O and CO_2. The error in loss of weight determinations is reduced to as low as 0.05%. A.P.

Determination of dichromates in the presence of chromates. ANTONINO SCONZO AND LUIGI MARSENGO. *Industria chimica*, **9**, 1163–67 (1934); *Chem. Abs.*, **28**, 7199 (1934).—The method is based on the reaction (1) $Cr_2O_7^{--} + 2OH^- \rightarrow 2CrO_4^{--} + H_2O$. Add an excess of alkali to the mixture of chromates and dichromates, precipitate the CrO_4^{--} with $BaCl_2$, and determine the excess alkali with methyl orange as indicator. The exact amount of Ba must be added, since with insufficient amount the solution remains colored (this interferes with the titration) and an excess causes precipitation of $BaCO_3$ ($BaCrO_4 + CO_3^{--} \rightarrow BaCO_3 + CrO_4^{--}$). The amount of $BaCl_2$ to be added is calculated by titrating the mixture of CrO_4 and Cr_2O_7 with I_2 and thiosulfite solution, the volume of 0.1 *N* $BaCl_2$ to be added to the solution being 2/3 *V'*, where *V'* is the volume of thiosulfite used.

Determination of ferrous iron in materials containing metallic iron and ferric iron. T. TAZAWA. *Seitetsu Kenkyu*, No. 134 (1933); *Chem. Abs.*, **28**, 7200 (1934).—In a mixture of metallic Fe with Fe oxides, the free Fe is removed by treatment with $HgCl_2$ solution, the precipitated Hg is removed by alcohol I solution, the residue containing ferrous and ferric oxides is dissolved in HCl in an atmosphere of CO_2, and the solution titrated directly for ferrous iron after addition of Reinhardt's $MnSO_4$ solution. The metallic iron can be determined in the filtrate from the treatment with $HgCl_2$ solution, the total Fe determined on a separate sample, and the ferric oxide then found by difference.

Fluorescence spectrum of apatite in ultra-violet light. EIICHI IWASE. *Sci. Papers Inst. Phys. Chem. Research*, **27** [567] 1–9 (1935).—The fluorescence spectrum of twelve samples of apatite has been determined. The fluorescence band of apatite occurring with ores is much broader than that of apatite associated with basic igneous rocks. Table-like crystals show a wide band, and columnar crystals a narrow band. J.B.A.

Investigating thermal changes occurring during transformations in a solid solution. C. SYKES. *Proc. Roy. Soc.* [London], **A148**, 422–46 (1935).—The standard cooling-curve methods for determining the temperatures at which an alloy undergoes transformations give unreliable results when applied to changes occurring over a range in temperature, such as atomic rearrangement in homogeneous solid solutions. A double differential cooling-curve method takes into account the temperature of the enclosure throughout the cooling period. To determine quantitatively the heat involved in such transformations, a method has been developed for measuring specific heat as the temperature is continuously varied. A.P.

Investigations of a portion of the quaternary system CaO–Al_2O_3–SiO_2–Fe_2O_3. The quaternary system CaO–$2CaO{\cdot}SiO_2$–$5CaO{\cdot}3Al_2O_3$–$4CaO{\cdot}Al_2O_3{\cdot}Fe_2O_3$. F. M. LEA AND T. W. PARKER. *Phil. Trans. Roy. Soc.* [London], **A234**, 1–41 (1934); *Chem. Abs.*, **29**, 2431 (1935).—The phase relations in the following systems were studied: $2CaO{\cdot}SiO_2$ (II)–$4CaO{\cdot}Al_2O_3{\cdot}Fe_2O_3$ (IV); CaO (I)–II–IV; II–$5CaO{\cdot}3Al_2O_3$ (III)–IV; I–II–III–IV. No new compounds were observed. The following invariant points

were found in these systems: 1 in the binary, 1 in the first ternary, 2 in the second ternary, and 3 in the quaternary. Temperature relations and crystallization paths are discussed. The compound $3CaO \cdot SiO_2$ is unstable in this system below 1250° and above 1900°, giving the same decomposition products in either case. The lower decomposition point is a definite temperature at which the whole compound is dissociated though the actual rate of decomposition is small.

Melting phenomena in relation to a new equation of state and to the lattice structure of solids. S. Franchetti. *Lincei rend.*, **19** [11] 800–803 (1934); *Physik. Ber.*, **16** [2] 128–29 (1935).—The discontinuation of volume and interior energy and the unstable conditions occurring between the solid and liquid states are expressed in a new equation derived from a discussion of the theories of other authors on interatomic forces. M.H.

Microchemical test for fluorine. S. K. Hagen. *Mikrochemie*, **15**, 313–15 (1934); abstracted in *Analyst*, **60**, 125 (Feb., 1935).—Amounts of HF insufficient to etch glass change its quality so that H_2SO_4 no longer runs smoothly over it. H.H.S.

Nature and properties of alumino-silicate framework structures. W. H. Taylor. *Proc. Roy. Soc.* [London], **A145**, 80 (1934).—The structures of feldspars and zeolites are based on strong frameworks of SiO_4 and AlO_4 tetrahedrons, sharing all corners with other tetrahedrons and with the cations and water molecules in the interstices. The fundamental unit is the tetrahedron of oxygen atoms, but all cases so far described contain as a secondary unit the ring of four tetrahedra in which it is usually impossible to distinguish the similar SiO_4 and AlO_4 groups. In isomorphous replacements a divalent cation may be replaced by (or replace) two monovalent cations only when there are within the framework some cavities which may be either occupied or empty as the number of cations varies. With the feldspars, divalent cations replace monovalent cations of the same size, the same cavities are always occupied, and valencies are balanced by alteration of the proportion of aluminium to silicon. Base exchange and the peculiar dehydration of zeolites are due to channels large enough to permit movement of cations and water molecules; the water molecules become oriented in such a way that their positive and negative bonds, arranged tetrahedrally, are satisfied by O ions and cations, respectively. Twinning is frequent in feldspars and zeolites because the frameworks possess a high structural symmetry to which the actual dimensional symmetry approximates. A.P.

Plasticity, the servant of industry. H. Freundlich. *Jour. Soc. Chem. Ind.*, **53** [29] 218–25 (1934).—The cause of plastic behavior is not the same in all cases, making it necessary to distinguish between molecular and colloidal plasticity, although the latter term is not strictly correct. Glass is a non-isothermal plastic material. To define plasticity exactly, the strength of the force and its rate of application must be known. Plastic masses can not be made from any powder and any liquid. Colloid plasticity is closely associated with the phenomena, shown by some plastic masses, of being amenable to the so-called clay-casting process and of giving hard, coherent masses on drying. The behavior of both kaolinite and bentonite seems to prove that some affinity between the solid and liquid is essential for the development of plasticity. Packing and sedimentation give an idea of the thickness of layers on the surface of grains. The phenomenon of thixotropy requires loose packing in solid-liquid systems and is frequently met in plastic masses. Casting and drying of clayware are discussed. G.R.S.

Quantitative precipitation of copper with tannic acid. M. B. Darbinian and A. G. Kankanian. *Z. anal. Chem.*, **99** [1–2] 29–32 (1934).—When the solution is heated, tannin gives a chestnut-colored precipitate with copper, but the precipitation is not quantitative unless the solution is buffered, *e.g.*, with NH_4OAc. The copper is reduced during the precipitation and 1 mol of tannin combines with 10 equivalents of copper. Complete precipitation is accomplished in NH_4OAc solution but not in the presence of excess ammonia. E.J.V.

Spot test for fluorides. F. Feigl and E. Rajmann. *Mikrochemie*, **12**, 133–36 (1933); *Analyst*, **59**, 304 (1934).—Fluorides turn to red the yellow brown compound of Zr with *p*-dimethylamino-azo-phenyl-arsenic acid. H.H.S.

Standard conditions for precise prism refractometry. Leroy W. Tilton. *Jour. Research Nat. Bur. Stand.*, **14** [4] 393–418 [1935]; R.P. 776. Price 5¢. R.A.H.

Thermal decomposition of some carbonate minerals. Roger C. Wells. *Trans. Amer. Geophys. Union, 15th Ann. Meeting*, Part I, pp. 237–40 (1934); *Chem. Abs.*, **28**, 7205 (1934).—The rate of CO_2 evolution from magnesite ($MgCO_3$) for a CO_2 gas pressure of 1 atmosphere is very slow below 560°. From 580 to 600° the rate increases slightly as decomposition proceeds up to a certain point, after which it slowly decreases. If calculated for 1 g. of undecomposed mineral, the rate of decomposition increases fairly rapidly for the first $^1/_3$ of the decomposition, and thereafter becomes fairly constant. Dissociation temperature has been reported as 402 to 680°; W. believes 545° is about right. Errors of determination with H_2O as a catalyst are discussed. Curves for thermal decomposition of brucite and hydromagnesite are given.

Two aspects of the representative method. J. Neyman. *Jour. Roy. Statistical Soc.*, **97**, 558 (1934).—A mathematically justifiable method of selective, purposive sampling would have many advantages over the random, stratified method. An example given is the testing of a kiln load of brick for strength and weathering resistance, in which average values are meaningless, but N. demonstrates that the present methods of purposive selection give results which can not be correlated with the true conditions. A.P.

Volumetric method for determining lead. I. Tananaev. *Z. anal. Chem.*, **99** [1–2] 18–21 (1934).—In determining fluorine, Starck used the following reaction: $NaF + PbCl_2 = PbFCl + NaCl$. The same reaction can be used for determining lead, having the advantage that only ions that form insoluble halides interfere. To the solution containing lead, add a measured volume of a solution containing exactly 8.400 g. NaF and 11.69 g. NaCl in 100 cc. After making up to a definite volume and mixing, determine the excess silver in an aliquot. To determine lead in bearing metal, dissolve 0.5 to 1.5 g. of alloy in concentrated nitric acid, dilute the resulting solution with water, and filter into a 100 cc. volumetric flask. Wash the filter with water and neutralize the fil-

trate with concentrated sodium hydroxide. Add an excess of sodium hydroxide to make the solution about 0.2 *N*. Then proceed as given above. Before titrating for the excess silver, it is well to make the solution neutral to phenolphthalein. B.J.V.

BOOKS

Geochemistry. A. E. FERSMAN. State Chem.-Tech. Pub. House, Leningrad, 1934. 2d ed., revised and enlarged. 324 pp. Price, cloth, 5R 50k. The book is the first of a four-volume work destined for large groups of scientific workers, university and technical high-school students, for geological, geologico-prospecting establishments, and research institutes working in the field of study and use of mineral raw materials. The correlation between geochemistry and other sciences (mineralogy, petrology, geology, soil science, geography, biochemistry, astrophysics, metereology, geophysics, crystallography and crystallochemistry, chemical physics, radiochemistry, physical chemistry, and philosophy) is discussed. The second chapter is devoted to the atom and crystal in geochemistry. The following chapters deal with the chemical composition of cosmic bodies and the structure and chemical composition of geospheres. S. I. PERKAL

Transactions of the VI All-Union Mendeleiev Congress of Theoretical and Applied Chemistry. Vol. 2. 1st ed. State Sci.-Tech. Pub. House of Ukraine, Kharkov-Kiev, 1935. 1006 pp. Price 27R 50k. The VI Mendeleiev Congress which was held in Kharkov Oct. 25 to Nov. 1, 1932, was organized in commemoration of the Russian chemist, D. I. Mendeleiev, the creator of the periodical system of chemical elements, representing the greatest theoretical generalization used in all investigations and researches of the chemist and physico-chemist, physicist and chemico-physicist, astrophysicist, and technologist. Abstracts of papers of interest from the ceramic point of view will be published in *Ceramic Abstracts*. S.I.P.

PATENTS

Hydrous silicate gels and method of making. E. W. REMBERT (Johns-Manville Corp.). U. S. 1,999,210, April 30, 1935 (April 10, 1931; July 26, 1934). In a process of producing insoluble silicates in finely divided form, the steps of disseminating a compound of alkaline earth metal in an alkaline aqueous medium and slowly adding a soluble silicate to such medium to form a silicate of such metal, the rate of addition of the soluble silicate being such as to maintain its concentration below that concentration at which an insoluble silicate having a dense granular structure and low adsorption efficiency is formed.

Manufacture and production of sodium aluminate. J. Y. JOHNSON (Pennsylvania Salt Mfg. Co.). Brit. 427,459, May 9, 1935 (Nov. 27, 1934).

Method of extracting oxide of beryllium direct from minerals containing it. GINO PANEBIANCO AND CARLO ADAMOLI. U. S. 1,998,685, April 23, 1935 (Aug. 28, 1931).

General

Determining acid resistance of natural stones, ceramic ware, and masses for chemical apparatus. ANON. *Trans. VI Mendeleiev Congress*, **2** [1] 313–14 (1935).—This method, representing a modification of the method of Kallauner-Barta, was developed by the All-Union Institute of Refractories and Acid-Resistant Materials (V.I.O.K.). For testing, take a ground specimen of such fineness that the grains pass through a sieve with 36 apertures/cm.^{2} and remain on a sieve with 64 apertures/cm.^{2} To separate the dust from the grains, wash them on the sieve with a stream of distilled water and then dry for 3 hr. in a drying chamber at 110°C. Place a 1-g. sample of the dried grains in a 500-cc. Erlenmeyer flask and pour in 25 cc. C.P. sulfuric acid (specific gravity 1.84) or, proportionately, 2, 20, or 50% nitric acid. Connect the flask by a rubber cork with a reflux (converse) ball cooler and heat (on a screen) on the full flame of a Teclu burner; bring the contents of the flask to boiling. Boil gently for 1 hr., then remove from the burner, and allow the flask to cool ½ hr. Wash the internal tube of the cooler and the stopper with a small quantity of water which is collected in a porcelain dish. Pour this water and those grains of the testing material which may be carried along with it into the cooled flask, the contents of which are first diluted by the gentle addition of 50 cc. of cold distilled water. After adding to the flask the pulp obtained by shaking up the filter in a small quantity of water, pour off the liquid gently from the flask through a funnel with a dense filter on the bottom of which is also placed some of the filter pulp. When all the liquid is passed through the filter, add 50 cc. of boiling water to the residue in the flask and shake this, again passing the liquid through the filter. The testing material remaining in the flask is washed in a porcelain dish with a stream of hot water from a washing bottle. The washing liquid is again filtered through the same filter. To the residue of material in the porcelain dish, add 20 cc. boiling water with 5 cc. of the solution of NH_4Cl (5%) and after filtering this liquid, transfer the whole residue onto the filter where it is washed with boiling water until the negative reaction on Cl' (the test with $AgNO_3$). Transfer the washed residue with the filter in a porcelain crucible, dry gently, ashing the filters, and ignite the residue in the full flame of a Teclu burner to constant weight. The acid resistance is calculated from the formula, $K = \frac{H_2 \cdot 100\%}{H_1}$, where K = acid resistance, H_1 = sample of material before test, and H_2 = sample of material after test. S.I.P.

Sericite in foundry dust. C. S. HURLBUT, JR., AND DAVID S. BEYER. *Jour. Ind. Hygiene*, **16** [3] 169–76 (1934).—A study of the dusts of two foundries carrying out similar operations showed that the dust in one was extremely high in sericite while the other had only a moderate amount. This difference was traced to the molding sands used. A high incidence of silicosis claims occurred in the foundry in which the dust was high in sericite in spite of lower dust counts and more favorable employment conditions in that foundry. No silicosis claims were made at the foundry having little sericite. The findings in these respects were in harmony with those of Jones (*Ceram. Abs.*, **14** [3] 84 (1935)). Petrographic analyses showed that 75% of the particles in one sand was

sericite (all of respirable size) while in another sand, used for similar purposes, no sericite whatever was found. A sericite-rich sand may contribute a large percentage of sericite particles to the respirable dust in a foundry, even though this sand is only a small portion of the total. Sericite particles, because of their shape, will remain suspended in the air longer than quartz particles of equal size. Further studies should be made to determine the sericite content of foundry sands, particularly those used when silicosis claims have arisen. Preference should be given to the use of foundry sands having little or no sericite. E.J.V.

Statistical method for control and standardization of the quality of manufactured products. E. S. PEARSON. *Jour. Roy. Statistical Soc.*, **96**, 21 (1933).—Statistical analysis can provide a scientific basis for the establishment of quality standards and guide research in maintaining those standards and in increasing efficiency in production. A.P.

Water softening for bodies and glazes. III. JOHN H. GRADY. *Ceram. Ind.*, **24** [5] 296–98 (1935).—Methods of determining alkalinity or hardness of turbid, acid waters or waters of low alkalinity and colored waters, and the determination of noncarbonate hardness by the soda-reagent method are described in detail. For Part II see *Ceram. Abs.*, **14** [6] 145 (1935). E.J.V.

BOOKS

Annual report of the Society of Chemical Industry on the progress of applied chemistry. Vol. XIX. Society of Chemical Industry, London, 1934. 840 pp. The developments made in all branches of the chemical industry during the past year are presented. Included are sections devoted to glassworking, the chemistry and physics of silicates, refractories, cements, and ceramics in general. While most of the references concern English developments, the important development work of American investigators is also well presented. M. C. SHAW

Levinson-Lessing, the Academician. *Trans. Petrographical Inst. Acad. Sci.* [U.S.S.R.], Vol. VI. Pub. House of the Academy of Sci., U.S.S.R., Leningrad, 1934. 492 pp. Price, cloth, 20R. Published to honor Frants Yulyevich Levinson-Lessing, this book contains a list of 180 papers published by L.-L. from 1884 to 1934. The many-sidedness of the author is shown. Abstracts of separate papers of interest to ceramists will be published in *Ceramic Abstracts*. S. I. PERKAL

Transactions of the All-Union Sci. Research Institute of Ceramics. 45th issue. State Pub. House of Light Ind., Leningrad, 1934. 100 pp. Price 2R 25k. The State Research Institute of Ceramics (G.I.K.I.), the oldest ceramic research institute in the Soviet Union, was recently reorganized in the All-Union Sci.-Research Institute of Ceramics (V.N.I.I.K.). The volume contains a series of interesting research works of this Institute as follows: (1) "Action of chlorine on kaolinite," by N. K. Antonyevich. Research has established the fact that in fired kaolin the silica and alumina are chemically combined, *i.e.*, as a result of dehydration of kaolinite the kaolin anhydride, $2SiO_2 \cdot Al_2O_3$, is obtained, but not a mixture of free oxides. (2) "Method of estimating zirconium," by N. A. Zhirnova. A review of literature on old and new methods of zirconium determination is given. Experimental verification and comparison were made of the methods (selenious and phenylarsin) with the old methods (phosphate, hyposulfite) on zirconium salts and silicate-zirconium masses and ores. For the estimation of Zr in the masses and ores, Z. recommends the phenylarsin and selenious (selenious acid, H_2SeO_3) methods as the best. (3) "Melting diagram of the system ZrO_2–SiO_2," by N. A. Zhirnova. After a review of the works of Doelter, Washburn and Libman, Matignon, Wartenberg, and Gurr, Z.'s experiments are outlined. The conclusions are of especial interest to refractories manufacturers. The liquidus line in the system ZrO_2–SiO_2 was estimated. The existence on the liquidus line of a maximum corresponding to the molecular ratio, $ZrO_2:SiO_2 = 1:1$, was confirmed. This may serve as proof of the formation of the chemical compound $ZrSiO_4$, melting at 2430°C but not at 2550°C, as has been found by Washburn and Libman. The system ZrO_2–SiO_2 has two eutectics: one corresponding to 42% SiO_2 with a eutectic temperature of 2220°C and the second containing 97% SiO_2 with the eutectic temperature 1705°C. The melting diagram of the system ZrO_2–SiO_2 marks the existence of a field of solid solutions from the side of ZrO_2, the limit of spreading being nearly 10 mol. % of SiO_2. (4) "Glassy phase in porcelain," by G. A. Ssokolov and V. A. Onissimo-Yanovski. (5) "Packing of grains of different fractions and the influence of granulometric composition on the properties of a body." (See "Granulometric—" *Ceram. Abs.*, **14** [5] 116 (1935); "Production—" *ibid.*, **14** [6] 142 (1935)). The researches are fundamental and will be of value to every ceramist interested in the subjects. S. I. PERKAL

PATENTS

Clay composition and articles made therefrom. C. S. EDMONDSON. Brit. 427,326, May 9, 1935 (Oct. 19, 1933).

Manufacture of artificially colored granules. M. R. BEASLEY (Bird & Son, Inc.). U. S. 2,001,448, May 14, 1935 (May 2, 1934).

Method of indurating clay and product formed therefrom. M. H. KLIEFOTH (C. F. Burgess Laboratories Inc.). U. S. 2,000,338, May 7, 1935 (July 28, 1932). The method for indurating clay or clay-like materials comprises disseminating a small amount of caustic alkali throughout the material and heating the mixture at a temperature substantially above 110°C but not above 500°C to produce a nonvitrified product having hardness approximating that of clay fired at a temperature near its fusion point.

Process for producing cellular ceramic products. J. R. PARSONS (United States Gypsum Co.). U. S. 1,998,686, April 23, 1935 (Sept. 9, 1933). The process of casting clay articles comprises mixing clay, water, a deflocculant, and a neutral alkali salt, agitating the mixture, and rapidly placing it into molds wherein the mixture stiffens or gels to form a soft coherent mass when left at rest.

Treatment of argillaceous material. ALLIED PROCESS CORP. Brit. 409,621, May 9, 1934 (Jan. 3, 1933).

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Abrasive Industry
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American Glass Review
American Refractories Institute Technical Bulletin
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Better Enameling
Bibliographia Italiana
Brick & Clay Record
British Clayworker
Bulletin of the American Society for Testing Materials
Bulletin of the British Non-Ferrous Metals Research Assn.
Canadian Chemistry and Metallurgy
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Transactions of the Ceramic Research Institute (Leningrad)
Transactions of the Ceramic Society (English)
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Ukrainian Chemical Journal
Verre et Silicates Industriels
Zeitschrift für praktische Geologie
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